PHILOSOPHICAL

TRANSACTIONS,

OF THE

ROYAL SOCIETY

OF

LONDON.

FOR THE YEAR MDCCCXIII.

PART I.

LONDON,

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PART I.

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ADVERTISEMENT.

THE Committee appointed by the *Royal Society* to direct the publication of the *Philosophical Transactions*, take this opportunity to acquaint the Public, that it fully appears, as well from the council-books and journals of the Society, as from repeated declarations which have been made in several former *Transactions*, that the printing of them was always, from time to time, the single act of the respective Secretaries, till the Forty-seventh Volume: the Society, as a Body, never interesting themselves any further in their publication, than by occasionally recommending the revival of them to some of their Secretaries, when, from the particular circumstances of their affairs, the *Transactions* had happened for any length of time to be intermitted. And this seems principally to have been done with a view to satisfy the Public, that their usual meetings were then continued, for the improvement of knowledge, and benefit of mankind, the great ends of their first institution by the Royal Charters, and which they have ever since steadily pursued.

But the Society being of late years greatly enlarged, and their communications more numerous, it was thought advisable that a Committee of their members should be appointed, to reconsider the papers read before them, and select out of them such as they should judge most proper for publication in the future *Transactions*; which was accordingly done upon the 26th of March, 1752. And the grounds of their choice are, and will continue to

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be, the importance and singularity of the subjects, or the advantageous manner of treating them; without pretending to answer for the certainty of the facts, or propriety of the reasonings, contained in the several papers so published, which must still rest on the credit or judgment of their respective authors.

It is likewise necessary on this occasion to remark, that it is an established rule of the Society, to which they will always adhere, never to give their opinion, as a Body, upon any subject, either of Nature or Art, that comes before them. And therefore the thanks which are frequently proposed from the Chair, to be given to the authors of such papers as are read at their accustomed meetings, or to the persons through whose hands they receive them, are to be considered in no other light than as a matter of civility, in return for the respect shewn to the Society by those communications. The like also is to be said with regard to the several projects, inventions, and curiosities of various kinds, which are often exhibited to the Society; the authors whereof, or those who exhibit them, frequently take the liberty to report, and even to certify in the public newspapers, that they have met with the highest applause and approbation. And therefore it is hoped, that no regard will hereafter be paid to such reports and public notices, which in some instances have been too lightly credited, to the dishonour of the Society.

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Meteorological Journal kept at the Apartments of the Royal Society, by Order of the President and Council.

ERRATUM.

Page 50, line 4, *for* concave *read* convex.

PHILOSOPHICAL TRANSACTIONS.

I. *On a new detonating Compound, in a Letter from Sir* HUMPHRY DAVY, *L.L.D. F.R.S. to the Right Honourable Sir* JOSEPH BANKS, *Bart. K.B. P.R.S.*

Read November 5, 1812.

MY DEAR SIR,

I THINK it right to communicate to you, and through you to the Royal Society, such circumstances as have come to my knowledge respecting a new and a very extraordinary detonating compound. I am anxious that those circumstances should be made public as speedily as possible, because experiments upon the substance may be connected with very dangerous results; and because I have already mentioned the mode of preparing it to many of my chemical friends, to whom my experience may be useful in saving them from danger.

About the end of September, I received a letter from a philosophical gentleman at Paris on some subjects of science, which contained the following paragraph:

"Vous avez sans doute appris, Monsieur, la découverte qu'on a faite à Paris il y a près d'un an, d'une combinaison de gaz azote et de chlorine, qui a l'apparence d'une huile plus

pesante que l'eau, et qui détonne avec toute la violence des métaux fulminans à la simple chaleur de la main, ce qui a privé d'un œil et d'un doigt l'auteur de cette découverte. Cette détonnation a lieu par la simple separation des deux gaz, comme celle de la combinaison d'oxigène et de chlorine ; il y a également beaucoup de lumière et de la chaleur produites dans cette détonnation, où un liquide se decompose en deux gaz."

The letter contained no account of the mode of preparation of this substance, nor any other details respecting it.

So curious and important a result could not fail to interest me, particularly as I have long been engaged in experiments on the action of azote and chlorine, without gaining any decided proofs of their power of combining with each other. I perused with avidity the different French chemical and physical journals, especially *Les Annales de Chimie*, and *Le Journal de Physique*, of which the complete series of last year have arrived in this country, in hopes of discovering some detail respecting the preparation of this substance, but in vain. I was unable to find any thing relative to it in these publications, or in the *Moniteur*.

It was evident from the notice, that it could not be formed in any operations in which heat is concerned; I therefore thought of attempting to combine azote and chlorine under circumstances which I had never tried before, that of presenting them to each other artificially cooled, the azote being in a nascent state. For this purpose I made a solution of ammonia, cooled it by a mixture of ice and muriate of lime, and slowly passed into it chlorine, cooled by the same means. There was immediately a violent action, accompanied by fumes of a pecu-

liarly disagreeable smell; at the same time a yellow substance was seen to form in minute films on the surface of the liquor; but it was evanescent, and immediately resolved itself into gas. I was preparing to repeat the experiment, substituting the prussiate of ammonia and other ammoniacal compounds, in which less heat might be produced by the action of the chlorine, than in the pure solution of the gas, when my friend, Mr. J. G. CHILDREN, put me in mind of a circumstance of which he had written to me an account, in the end of July, which promised to elucidate the enquiry, viz. that Mr. JAMES BURTON, jun. in exposing chlorine to a solution of nitrate of ammonia, had observed the formation of a yellow oil, which he had not been able to collect so as to examine its properties, as it was rapidly dissipated by exposure to the atmosphere. Mr. CHILDREN had tried the same experiment with similar results.

I immediately exposed a phial, containing about six cubical inches of chlorine, to a saturated solution of nitrate of ammonia, at the temperature of about 50° in common day-light. A diminution of the gas speedily took place; in a few minutes a film, which had the appearance of oil, was seen on the surface of the fluid; by shaking the phial it collected in small globules, and fell to the bottom. I took out one of the globules, and exposed it in contact with water to a gentle heat: long before the water began to boil, it exploded with a very brilliant light, but without any violence of sound.

I immediately proposed to Mr. CHILDREN, that we should institute a series of experiments upon its preparation and its properties. We consequently commenced the operations, the results of which I shall describe. We were assisted in our

labours, which were carried on in Mr. CHILDREN's laboratory at Tunbridge, by Mr. WARBURTON.

It was found that the solution of oxalate of ammonia, or a very weak solution of pure ammonia, answered the purpose as well as the solution of nitrate of ammonia. It was formed most rapidly in the solution of ammonia, but it was white and clouded; and though less evanescent than in the strong solution I first used, it was far from being as permanent as in the solutions of nitrate and oxalate. The solution of prussiate of ammonia acted on by chlorine, afforded none of the peculiar oil; but produced white fumes, and became of a bright green colour. An attempt was made to procure the substance in large quantities, by passing chlorine into WOLFE's bottles, containing the different solutions, but a single trial proved the danger of this mode of operating; the compound had scarcely began to form, when, by the action of some ammoniacal vapour on chlorine, heat was produced, which occasioned a violent explosion, and the whole apparatus was destroyed.

I shall now describe the properties of the new substance. Its colour is very nearly that of olive oil, and it is as transparent, and more perfectly liquid. I have not been able to ascertain its specific gravity with accuracy, but it is probably above 1.6. Its smell is very nauseous, strongly resembling that of the combination of carbonic oxide and chlorine, discovered by my brother; and its effect on the eyes is peculiarly pungent and distressing. A little of it was introduced under water into the receiver of an air pump, and the receiver exhausted; it became an elastic fluid, and in its gaseous state was rapidly absorbed or decomposed by the water. When warm water

was poured into a glass containing it, it expanded into a globule of elastic fluid, of an orange colour, which diminished as it passed through the water.

I attempted to collect the products of the explosion of the new substance, by applying the heat of a spirit lamp to a globule of it, confined in a curved glass tube over water: a little gas was at first extricated, but long before the water had attained the temperature of ebullition, a violent flash of light was perceived, with a sharp report; the tube and glass were broken into small fragments, and I received a severe wound in the transparent cornea of the eye, which has produced a considerable inflammation of the eye, and obliges me to make this communication by an amanuensis. This experiment proves what *extreme* caution is necessary in operating on this substance, for the quantity I used was scarcely as large as a grain of mustard seed.

A small globule of it thrown into a glass of olive oil, produced a most violent explosion; and the glass, though strong, was broken into fragments. Similar effects were produced by its action on oil of turpentine and naphtha. When it was thrown into ether there was a very slight action; gas was disengaged in small quantities, and a substance like wax was formed, which had lost the characteristic properties of the new body. On alcohol it acted slowly, lost its colour, and became a white oily substance, without explosive powers. When a particle of it was touched under water by a particle of phosphorus, a brilliant light was perceived under the water, and permanent gas was disengaged, having the characters of azote.

When quantities larger than a grain of mustard seed were used for the contact with phosphorus, the explosion was always

so violent as to break the vessel in which the experiment was made. The new body, when acted upon under water by mercury, afforded a substance having the appearance of corrosive sublimate, and gas was disengaged. On tin foil and zinc it exerted no action; it had no action on sulphur, nor on resin. In their alcoholic solutions it disappeared as in pure alcohol. It detonated most violently when thrown into a solution of phosphorus in ether, or in alcohol. Phosphorus introduced into ether, into which a globule of the substance had been put immediately before, produced no effect. In muriatic acid it gave off gas rapidly, and disappeared without explosion. On dilute sulphuric acid it exerted no violent action. It immediately disappeared without explosion in LIBAVIUS's liquor, to which it imparted a yellow tinge.

It seems probable, from the general tenor of these facts, that the new substance is a compound of azote and chlorine; the same as, or analogous to, that mentioned in the letter from Paris. It is easy to explain its production in our experiments: the hydrogen of the ammonia may be conceived to combine with one portion of the chlorine to form muriatic acid, and the azote to unite with another portion of chlorine to form the new compound. The heat and light produced during its expansion into gaseous matter, supposing it to be composed of azote and chlorine, is without any parallel instance, in our present collection of chemical facts; the decomposition of euchlorine, which has been compared to it, is merely an expansion of matter already gaseous. The heat and light produced by its rarefaction, in consequence of decomposition, depend, probably, on the same cause as that which produces the flash of light in the discharge of the air gun.

The mechanical force of this compound in detonation, seems to be superior to that of any other known, not even excepting the ammoniacal fulminating silver. The velocity of its action appears to be likewise greater.

I am, my dear Sir,

with great respect, very sincerely your's,

H. DAVY.

II. *On a remarkable Application of* Cotes's *Theorem.* *By* J. F. W. Herschel, *Esq.* *Communicated by* W. Herschel, *LL. D. F. R. S.*

Read November 12, 1812.

LET a represent the semi-transverse axis of a conic section, ae the eccentricity, and consequently $a(1-e^2) = p$ the semi-parameter.

Let also $\lambda = \frac{e}{1+\sqrt{1-e^2}}$ and $\lambda' = \frac{e^{-1}}{1+\sqrt{1-e^{-2}}}$.

$r^{(1)}$ = the distance between a point in the curve, and the focus, which, for distinction's sake, we shall call the first focus, and the adjacent vertex the first vertex: the others the second.

$r^{(2)}$ = the distance between the same point and the second focus.

R = its distance from the centre.

ρ = its distance from the first vertex.

θ = the angle contained between the $r^{(1)}$, and the *prolongation* of a line joining the first vertex and focus.

φ = the angle contained between the R and a line joining the first vertex and centre.

ψ = the angle contained between the ρ and the same line.

$$\tan.\tfrac{1}{2}\varpi = \sqrt{\tfrac{1-e}{1+e}}.\cot.\tfrac{1}{2}\theta = \tfrac{1-\lambda}{1+\lambda}.\cot.\tfrac{1}{2}\theta = \sqrt{-1}.\tfrac{1-\lambda'}{1+\lambda'}.\cot.\tfrac{1}{2}\theta.$$

θ is the angle whose supplement is, in physical astronomy, known by the name of "true anomaly," and ϖ is the corresponding "eccentric anomaly."

The following equations are readily obtained.

$$r^{(1)} = \frac{a(1-e^2)}{1-e\,.\,\cos.\,\theta}\text{;}\quad \text{and } r^{(2)} = 2a - r^{(1)} = a\,.\,\frac{1-2e\,.\,\cos.\,\theta+e^2}{1-e\,.\,\cos.\,\theta}.$$

$$r^{(1)} = a\left(1-e\,.\,\cos.\,\varpi\right);\ r^{(2)} = a\left(1+e\,.\,\cos.\,\varpi\right)$$

$$R^2 = \frac{a^2(1-e^2)}{1-e^2\,.\,(\cos.\,\phi)^2}$$

$$\rho = \frac{2a\left(1-e^2\right)\,.\,\cos.\,\psi}{1-e^2\,.\,(\cos.\,\psi)^2} = \frac{2\rho\,.\,\cos.\,\psi}{1-e^2\,.\,(\cos.\,\psi)^2}.$$

$$2e = \lambda' + \lambda'^{-1} \text{ and } 2\,.\,e^{-1} = \lambda + \lambda^{-1}.$$

Hence we deduce the following

$$r^{(1)} = a\,.\,\frac{(1-e^2)(1+\lambda^2)}{1-2\lambda\,.\,\cos.\,\theta+\lambda^2} \quad \ldots\ldots\ldots\ldots \{1\}$$

$$r^{(2)} = a\left(1+\lambda^2\right).\,\frac{1-2e\,.\,\cos.\,\theta+e^2}{1-2\lambda\,.\,\cos.\,\theta+\lambda^2} \quad \ldots\ldots\ldots\ldots \{2\}$$

$$\frac{r^{(2)}}{r^{(1)}} = \frac{1-2e\,.\,\cos.\,\theta+e^2}{1-e^2} \quad \ldots\ldots\ldots\ldots \{3\}$$

again $r^{(1)} = a\,.\,\dfrac{1-2\lambda\,.\,\cos.\,\varpi+\lambda^2}{1+\lambda^2}$ $\ldots\ldots\ldots\ldots \{4\}$

$$r^{(2)} = a\,.\,\frac{1-2\lambda\,.\,\cos.\,(\varpi-\varpi)+\lambda^2}{1+\lambda^2} \quad \ldots\ldots\ldots\ldots \{5\}$$

where $\varpi = 4\left\{1-\frac{1}{3}+\frac{1}{5}-\frac{1}{7}+\text{&c.}\right\}$.

$$\frac{r^{(1)}}{r^{(2)}} = \frac{1-2\lambda\,.\,\cos.\,\varpi+\lambda^2}{1-2\lambda\,.\,\cos.\,(\varpi-\varpi)+\lambda^2} \quad \ldots\ldots\ldots\ldots \{6\}$$

$$R^2 = \frac{a^2(1-e^2)(1+\lambda^2)^2}{\left\{1-2\lambda\,.\,\cos.\,\rho+\lambda^2\right\}\left\{1-2\lambda\,.\,\cos.\,(\varpi-\rho)+\lambda^2\right\}} \quad \ldots\ldots \{7\}$$

$$\rho = \frac{2a(1-e^2)(1+\lambda^2)^2\,.\,\cos.\,\psi}{\left\{1-2\lambda\,.\,\cos.\,\psi+\lambda^2\right\}\left\{1-2\lambda\,.\,\cos.\,(\varpi-\psi)+\lambda^2\right\}} \quad \ldots\ldots \{8\}$$

And lastly, since $1-e\,.\,\cos.\,\varpi = \frac{1-e^2}{1-e\,.\,\cos.\,\beta}$, we find $\cos.\,\theta =$

$$\left.\begin{aligned} e^{-1} + \frac{e-e^{-1}}{1-e\,.\,\cos.\,\varpi} &= \frac{e\left(1-e^{-2}\,.\,\cos.\,\varpi\right)}{1-e\,.\,\cos.\,\varpi} \\ &= e\,.\,\frac{1+\lambda^2}{1+\lambda^4}\,.\,\frac{1-2\lambda^2\,.\,\cos.\,\varpi+\lambda^4}{1-2\lambda\,.\,\cos.\,\varpi+\lambda^2} \\ &= e^{-1}\,.\,\left\{\frac{\lambda}{\lambda^2}\right\}.\,\frac{1-2\lambda^2\,.\,\cos.\,\varpi+\lambda^4}{1-2\lambda\,.\,\cos.\,\varpi+\lambda^2}. \end{aligned}\right\} \quad \ldots\ldots \{9\}$$

Before we proceed to the application of these transformations, it will be necessary to premise some properties of the functions λ and λ'.

Let $a = \cos.^{-1}(e^{-1})$ and $a' = \cos.^{-1} e$.*

* This notation $\cos.^{-1} x$ must not be understood to signify $\frac{1}{\cos. x}$, but what is usually written thus, arc $(\cos. = x)$. It is true that many authors use $\cos.^n A$, $\sin.^n A$, &c. for $(\cos. A)^n$, $(\sin. A)^n$; lest therefore the notation here adopted should appear capricious, it will not be irrelevant to explain its grounds. If φ be the characteristic mark of an operation performed on any symbol, x, $\varphi(x)$ may represent the result of that operation. Now to denote the repetition of the same operation, instead of $\varphi(\varphi(x))$; $\varphi(\varphi(\varphi(x)))$; &c. we may most elegantly write $\varphi^2(x)$; $\varphi^3(x)$; &c. Thus we use d^2x, Δ^3x, Σ^4x, for ddx, $\Delta\Delta\Delta x$, $\Sigma\Sigma\Sigma\Sigma x$, &c. By the same analogy, since $\sin. x$, $\cos. x$, $\tan. x$, $\log. x$, &c. are merely *characteristic marks* to signify certain algebraic operations performed on the symbol x, (such as

$$\frac{\left\{1+\frac{1}{1}+\frac{1}{1.2}+\frac{1}{1.2.3}+\&c.\right\}^{x\sqrt{-1}}-\left\{1+\frac{1}{1}+\frac{1}{1.2}+\frac{1}{1.2.3}+\&c.\right\}^{-x\sqrt{-1}}}{2\sqrt{-1}}$$

&c.) we ought to write $\sin.^2 x$ for $\sin. \sin. x$, $\log.^3 x$ for $\log. \log. \log. x$, and so on. To apply this to the inverse functions, we have $\varphi^n \varphi^{-n}(x) = \varphi^{n+-n}(x)$. Hence if $m = -n$ $\varphi^n \varphi^{-n}(x) = \varphi^0(x) = x$. with the operation (φ) performed *no times* on it, or merely x, that is, $\varphi^{-n}(x)$ must be such a quantity that its nth (φ) shall be x, or in other words $\varphi^{-n}(x)$ must represent the nth *inverse* function. It frequently happens that a peculiar characteristic symbol is appropriated to the inverse function. Let it be $\downarrow$, then $\varphi^{-n}, x = \downarrow^n, x$, and $\varphi^n x = \varphi^{2n}, \varphi^{-n}, x = \varphi^n(\varphi^n, \downarrow^n, x)$, hence $\downarrow^n, \varphi^n, x = x$, and therefore $\downarrow^{-n} x = \downarrow^{-n} \downarrow^n \varphi^n, x = \varphi^{1+n}, x$. For instance $d^{-n} V = \int^n V$, $d^n V = V$. $-\Sigma^{-n}, x = \Delta^n x$, $a^n = 1$, with the operation of multiplying by a, n times performed on it, and $\therefore a^{-n} = 1$, with the inverse operation so often performed on it, $= \frac{1}{a^n}$; $a^0 = 1$. Similarly $\sin.^{-n} x = \text{arc } (\sin. = x)$, $\cos.^{-n} x = \text{arc } (\cos.^n = x)$ &c.—and if $e = 1 + \frac{1}{1} + \frac{1}{1.2} + \&c.$ $x = \log. c^x$ and $\therefore c^x = \log.^{-1} x$, $c^{c^x} = \log.^{-2} x$, and $c^{c^{c^{\ldots\ldots(n)^x}}} = \log.^{-n} x$, or the nth inverse logarithm of x. It is easy to carry on this idea, and its application to many very difficult operations in the higher branches will evince that it is somewhat more than a mere arbitrary contraction.

wherefore cos. $\alpha = \frac{\lambda+\lambda^{-1}}{2}$ and cos. $\alpha' = \frac{\lambda'+\lambda'^{-1}}{2}$.

Thus, $\lambda = c^{\alpha\sqrt{-1}}$ and $\lambda' = c^{\alpha'\sqrt{-1}}$, where $c = 1 + \frac{1}{1} + \frac{1}{1.2} + \frac{1}{1.2.3}$ + &c. Hence, $\lambda^n + \lambda^{-n} = 2$. cos. $n\alpha$, and $\lambda'^n + \lambda'^{-n} = 2$. cos. $n\alpha'$; $\lambda^n - \lambda^{-n} = 2\sqrt{-1}$. cosin. $n\alpha$, $\lambda'^n - \lambda'^{-n} = 2\sqrt{-1}$. sin. $n\alpha'$. Consequently, if k be any arc

$1 - 2\lambda^n$. cos. $k + \lambda^{2n} = \lambda^n \left\{\lambda^n + \lambda^{-n} - 2 \text{ . cos. } k\right\} = 4\lambda^n$. sin. $\left(\frac{k+n\alpha}{2}\right)$. sin. $\left(\frac{k-n\alpha}{2}\right)$.

In like manner

$1 - 2\lambda'^n$. cos. $k + \lambda'^{2n} = 4\lambda'^n$. sin. $\left(\frac{k+n\alpha'}{2}\right)$. sin. $\left(\frac{k-n\alpha'}{2}\right)$.

We will now proceed to the application of these equations, and first, in Equation $\left\{1\right\}$ for θ substitute, successively, each of a series of angles

$$\underset{1}{\theta};\ \theta + \frac{2\pi}{n} = \underset{2}{\theta};\ \theta + \frac{4\pi}{n} = \underset{3}{\theta};\ \ldots\ldots\ \theta + \frac{2(n-1)\pi}{n} = \underset{n}{\theta}.$$

And let the resulting values of $r^{(1)}$ be

$$\underset{1}{r^{(1)}};\ \underset{2}{r^{(1)}};\ \ldots\ldots\ldots\ldots\ \underset{n}{r^{(1)}}$$

we have then

$$\underset{1}{r^{(1)}} \cdot \underset{2}{r^{(1)}} \ldots\ldots \underset{n}{r^{(1)}} = a^n \cdot \frac{(1-c^{\alpha})^r (1+\lambda^{\alpha})^r}{1 - 2\lambda^{\alpha} \text{ . cos. } n\theta + \lambda^{2\alpha}} \ldots\ldots\ldots\ldots \left\{1,1\right\}$$

for the product of the several denominators of the $r^{(1)}$ will be

$\left\{1 - 2\lambda \text{ . cos. } \underset{1}{\theta} + \lambda^2\right\}\left\{1 - 2\lambda \text{ . cos. } \underset{2}{\theta} + \lambda^2\right\}\ldots\ldots\left\{1 - 2\lambda \text{ . cos. } \underset{n}{\theta} + \lambda^2\right\} = 1 - 2\lambda^n$. cos. $n\underset{1}{\theta} + \lambda^{2n}$ by Cotes's theorem.

This equation appears under an imaginary form when $e > 1$, but, since cos.$^{-1} e$ is then a real angle, if we express it in α,

it will then be free from imaginary symbols; thus

$$r_1^{(1)} \ldots\ldots r_n^{(1)} = \frac{a^n(1-e^2)^n(\lambda+\lambda^{-1})^n}{\lambda^n+\lambda^{-n}-2\cdot\cos.\,n\theta} = \frac{\left\{2p\cdot\cos.\frac{\theta}{2}\right\}^n}{4\cdot\sin.\frac{n(\theta+\alpha)}{2}\cdot\sin.\frac{n(\theta-\alpha)}{2}}\left\{1,2\right\}.$$

When $e=1$, or the conic section is a parabola, $\lambda=1$, and we find

$$r_1^{(1)} \ldots\ldots r_n^{(1)} = \frac{(2p)^n}{2\left\{1-\cos.\,n\theta\right\}} = (2p)^{n-1}\times\frac{p}{2}\cdot\operatorname{cosec.}\left(\frac{n\theta}{2}\right)^2\left\{1,3\right\}.$$

A result of such remarkable simplicity, as deserves a more particular enunciation. Let then, in the diagram, fig. 1, S represent the focus of a parabola A,P,Q, and, having drawn any line SP_1, make n angles PSP_1, PSP_2 .... PSP_n, about S, all equal to each other; draw the axis ASM, and make the angle MSQ = n times MSP_1; and if L represent the latus rectum, we shall have

$$SP_1 \cdot SP_2 \ldots\ldots SP_n = L^{n-1}\cdot SQ,$$

for, by the polar equation of the curve, $SQ = \frac{p}{2}\cdot\operatorname{cosec.}\left(\frac{MSQ}{2}\right)^2$.

Thus, if SP_1 be coincident with SA, and n be odd, $\operatorname{cosec.}\frac{n\theta}{2}=1$, and $SP_1 \ldots. SP_n = \frac{1}{4}L^n$ . . . . . $\left\{1,4\right\}$;

but, if SP_1 be *perpendicular* to SA, and n still odd, $\operatorname{cosec.}\frac{n\theta}{2}=\sqrt{2}$. and $SP_1 \ldots. SP_n = \frac{1}{2}L^n$ . . . . . $\left\{1,5\right\}$.

If SP_1 be perpendicular to SA, but n of the form $4m+2$

$SP_1 \ldots. SP_n = \frac{1}{4}L^n$ . . . . . $\left\{1,6\right\}$.

Lastly, if the angle MSP $= \frac{\pi}{3}$, we shall find, provided n be of the form $6m + 1$,

$$SP_1 \ldots SP_n = L^n \ldots \ldots \ldots \left\{1,7\right\}.$$

Let us now resume the general equation $\left\{1,1\right\}$ and first, let $\theta = o$, or, let one of the $r^{(1)}$ terminate in the second vertex, we have, for every value of n,

$$r^{(1)}_1 \ldots r^{(1)}_n = p^n \cdot \frac{(1+\lambda^2)^n}{(1-\lambda^2)^n} = p^n \cdot \frac{(\lambda+\lambda^{-1})^n}{(\lambda^{\frac{n}{2}} - \lambda^{-\frac{n}{2}})^n} = -\frac{(2p)^n}{4} \cdot \frac{(\cos. \alpha)^n}{\left(\sin. \frac{n\alpha}{2}\right)^2}.$$

$\left\{1,8\right\}$.

2. Let $\cos. n\theta = -1$, and we obtain

$$r^{(1)}_1 \ldots r^{(1)}_n = p^n \cdot \frac{(1+\lambda^2)^n}{(1+\lambda^2)^n} = p^n \cdot \frac{(\lambda+\lambda^{-1})^n}{(\lambda^{\frac{n}{2}} + \lambda^{-\frac{n}{2}})^n} = \frac{(2p)^n}{4} \cdot \frac{(\cos. \alpha)^n}{\left(\cos. \frac{n\alpha}{2}\right)^2},$$

$\left\{1,9\right\}$.

This embraces all the cases where n is of the form $(2m+1)\frac{\pi}{\theta}$, and among the rest, when n is any odd number, and one of the $r^{(1)}$ terminates in the first vertex; when n is of the form $4m + 2$, and one of the $r^{(1)}$ perpendicular to the axis, &c.

3. Let $\cos. n\theta = o$; then

$$r^{(1)}_1 \ldots r^{(1)}_n = p^n \cdot \frac{(1+\lambda^2)^n}{1+\lambda^{2n}} = p^n \cdot \frac{(\lambda+\lambda^{-1})^n}{\lambda^n+\lambda^{-n}} = \frac{(2p)^n}{2} \cdot \frac{(\cos. \alpha)^n}{\cos. n\alpha} \left\{1,10\right\}.$$

This includes the cases where n is of the form $(2m+1) \cdot \left(\frac{\pi}{2}\right) \frac{1}{\theta}$, as for instance, where one of the $r^{(1)}$ is perpendicular to

the axis and n odd, or, one inclined at an angle $\frac{\pi}{4}$, and n of the form $4m + 2$, or, lastly, where $\theta = \frac{\pi}{6}$ and $n = 6m + 3$.

4. Let $\cos. n\theta = \frac{1}{2}$, then

$$r^{(1)}_{1} \ldots r^{(1)}_{n} = p^{n} \cdot \frac{(1+\lambda^{n})^{2}}{1-\lambda^{n}+\lambda^{2n}} = p^{n} \cdot \frac{(1+\lambda^{n})^{2} \cdot (1+\lambda^{n})}{1+\lambda^{3n}} \cdot \left\{1,11\right\}.$$

This takes place whenever n is of the form $(6m + 1) \cdot \frac{\left(\frac{\pi}{3}\right)}{\theta}$, as when $\theta = \frac{\pi}{3}$ and $n = (6m + 1)$; $\theta = \frac{\pi}{6}$, and $n = 12m + 2$, &c.

5. Let $\cos. n\theta = -\frac{1}{2}$, then

$$r^{(1)}_{1} \ldots r^{(1)}_{n} = p^{n} \cdot \frac{(1+\lambda^{n})^{2}}{1+\lambda^{n}+\lambda^{2n}} = p^{n} \cdot \frac{(1+\lambda^{n})^{2} \cdot (1-\lambda^{n})}{1-\lambda^{3n}} \cdot \ldots \left\{1,12\right\}.$$

Here n must be of the form $\frac{2\pi}{3\theta} \cdot (3m + 1)$, and if $\theta = \frac{2}{3}\pi$, n is of the form $3m + 1$.

We will now proceed to our second equation $\left\{2\right\}$, and by an operation exactly similar to that from which we obtained the equation $\left\{1,1\right\}$, we shall find

$$r^{(2)}_{1} \ldots r^{(2)}_{n} = a^{n} (1 + \lambda^{2n})^{n} \cdot \frac{1-2\epsilon^{n} \cdot \cos. n\theta + \epsilon^{2n}}{1-2\lambda^{n} \cdot \cos. n\theta + \lambda^{2n}} \cdot \ldots \left\{2,2\right\}$$

$$= a^{n} (\lambda + \lambda^{-1})^{n} \cdot \frac{1-2\epsilon^{n} \cdot \cos. n\theta + \epsilon^{2n}}{\lambda^{n} + \lambda^{-n} - 2 \cdot \cos. n\theta} = \frac{a^{n} \left\{1-2\epsilon^{n} \cdot \cos. n\theta + \epsilon^{2n}\right\}}{4 \cdot \sin. \frac{n(\theta+\alpha)}{2} \cdot \sin. \frac{n(\theta-\alpha)}{2}}$$

This transformation in z, however, as it possesses no particular elegance in point of form, and much complexity, we shall henceforward omit, except in a few remarkable instances.

This equation, in the five particular cases just enumerated, gives

1. $n =$ any number, $\theta = 0$.

$$f^{(2)}_{1} \ldots\ldots f^{(2)}_{n} = a^{n}\,(1-e^{n})^{n} \cdot \frac{(1+\lambda^{2})^{n}}{(1-\lambda^{2})^{n}} \quad \ldots \quad \{2,2\}$$

2. $n = (2m+1) \cdot \frac{\pi}{0}$.

$$f^{(2)}_{1} \ldots\ldots f^{(2)}_{n} = a^{n} \cdot (1+\lambda^{2})^{n} \cdot \left(\frac{1+e^{n}}{1+\lambda^{n}}\right)^{2} \quad \ldots \quad \{2,3\}$$

3. $n = (2m+1) \cdot \frac{\pi}{2^{0}}$.

$$f^{(2)}_{1} \ldots\ldots f^{(2)}_{n} = a^{n} \cdot (1+\lambda^{2})^{n} \cdot \frac{1+e^{2n}}{1+\lambda^{2n}} \quad \ldots \quad \{2,4\}$$

4. $n = (6m+1) \cdot \frac{\pi}{3^{0}}$.

$$f^{(2)}_{1} \ldots\ldots f^{(2)}_{n} = a^{n} \cdot (1+\lambda^{2})^{n} \cdot \left(\frac{1+\lambda^{n}}{1+e^{n}}\right) \cdot \left(\frac{1+e^{2n}}{1+\lambda^{2n}}\right) \quad \ldots \quad \{2,5\}$$

5. $n = (6m+2) \cdot \frac{\pi}{3^{0}}$.

$$f^{(2)}_{1} \ldots\ldots f^{(2)}_{n} = a^{n} \cdot (1+\lambda^{2})^{n} \cdot \left(\frac{1-\lambda^{n}}{1-e^{n}}\right) \cdot \left(\frac{1-e^{2n}}{1-\lambda^{2n}}\right) \quad \ldots \quad \{2,6\}$$

Our third equation $\{3\}$, gives immediately

$$\frac{f^{(2)}_{1} \ldots\ldots f^{(n)}_{n}}{f^{(1)}_{1} \ldots\ldots f^{(1)}_{n}} = \frac{1-2e^{n} \cdot \cos. n\theta + e^{2n}}{(1-e^{2})^{n}} \quad \ldots \quad \{3,1\}$$

which, in the abovementioned cases, becomes

1. $$\frac{f^{(2)}_{1} \ldots\ldots f^{(2)}_{n}}{f^{(1)}_{1} \ldots\ldots f^{(1)}_{n}} = \frac{(1-e^{n})^{2}}{(1-e^{2})^{n}} \quad \ldots \quad \{3,2\}$$

2. $$\frac{f^{(2)}_{1} \ldots\ldots f^{(2)}_{n}}{f^{(1)}_{1} \ldots\ldots f^{(1)}_{n}} = \frac{(1+e^{n})^{2}}{(1-e^{2})^{n}} \quad \ldots \quad \{3,3\}$$

3. $\frac{r^{(2)}_{1} \ldots r^{(2)}_{n}}{r^{(1)}_{1} \ldots r^{(1)}_{n}} = \frac{1+\epsilon^{2n}}{(1-\epsilon^2)^n}$ . . . . . $\{3,4\}$

4. $\frac{r^{(2)}_{1} \ldots r^{(2)}_{n}}{r^{(1)}_{1} \ldots r^{(1)}_{n}} = \frac{1+\epsilon^{2n}}{(1+\epsilon^2)(1-\epsilon^2)^n}$ . . . . . $\{3,5\}$

5. $\frac{r^{(2)}_{1} \ldots r^{(2)}_{n}}{r^{(1)}_{1} \ldots r^{(1)}_{n}} = \frac{1-\epsilon^{2n}}{(1-\epsilon^2)(1-\epsilon^2)^n}$ . . . . . $\{3,6\}$.

Let us now, instead of taking equal angles round the first focus, take a series of eccentric anomalies, in arithmetical progression

$$\varpi_1; \varpi_2 = \varpi_1 + \tfrac{2\pi}{n}; \ldots\ldots \varpi_n = \varpi_1 + \tfrac{2(n-1)\pi}{n},$$

and let the resulting values of $r^{(1)}$ be, as before

$$r^{(1)}_1; r^{(1)}_2; \ldots\ldots r^{(1)}_n.$$

we get then, by the same process,

$$r^{(1)}_1 \ldots\ldots r^{(1)}_n = a^n \cdot \frac{1-2\lambda^n \cdot \cos. n\varpi + \lambda^{2n}}{(1+\lambda^2)^n} \quad . \quad . \quad . \{4,1\}$$

This gives, in the five cases; 1st, when n is any number, and $\varpi_1 = o$, (or one of the $r^{(1)}$ terminates in the first vertex); 2dly, when $n = (2m+1) \cdot \frac{\pi}{\varpi}$; 3dly, $n = (2m+1) \cdot \frac{\pi}{2\varpi}$; 4thly, $n = (6m+1) \cdot \frac{\pi}{3\varpi}$; and 5thly, $n = (6m+2) \cdot \frac{\pi}{3\varpi}$; the following equations

1. $r^{(1)}_1 \ldots\ldots r^{(1)}_n = a^n \cdot \frac{\left(\lambda^{\frac{n}{2}} - \lambda^{-\frac{n}{2}}\right)^2}{(\lambda+\lambda^{-1})^n}$ . . . . . $\{4,2\}$

2. $r^{(1)}_1 \ldots\ldots r^{(1)}_n = a^n \cdot \frac{\left(\lambda^{\frac{n}{2}} + \lambda^{-\frac{n}{2}}\right)^2}{\lambda+\lambda^{-1})^n}$ . . . . . $\{4,3\}$

3. $r^{(1)}_{1} \ldots\ldots r^{(1)}_{n} = a^n \cdot \frac{\lambda^n + \lambda^{-n}}{(\lambda + \lambda^{-1})^n} \cdot \ldots\ldots \left\{4,4\right\}$

4. $r^{(1)}_{1} \ldots\ldots r^{(1)}_{n} = a^n \cdot \frac{\left(\lambda^{\frac{n}{2}} + \lambda^{-\frac{n}{2}}\right)}{(\lambda + \lambda^{-1}) \cdot \left(\lambda^{\frac{1}{2}} + \lambda^{-\frac{1}{2}}\right)} \cdot \ldots\ldots \left\{4,5\right\}$

5. $r^{(1)}_{1} \ldots\ldots r^{(1)}_{n} = a^n \cdot \frac{\left(\lambda^{\frac{n}{2}} - \lambda^{-\frac{n}{2}}\right)}{(\lambda + \lambda^{-1}) \cdot \left(\lambda^{\frac{1}{2}} - \lambda^{-\frac{1}{2}}\right)} \cdot \ldots\ldots \left\{4,6\right\}.$

The Equation $\left\{5\right\}$ may be treated in the same manner, for the values of ϖ, being ϖ_1; $\varpi_1 + \frac{2\pi}{n}$; ..... $\varpi_1 + \frac{2(n-1)\pi}{n}$, those of $\pi - \varpi$ in an inverted order will be (if $\nu = -\left\{\varpi_1 + \frac{(n-2)\pi}{n}\right\}$)

$$\nu, \nu + \frac{2\pi}{n}, \ldots\ldots\ldots \nu + \frac{2(n-1)\pi}{n}.$$

Hence we find

$$r^{(2)}_{1} \ldots\ldots r^{(2)}_{n} = a^n \cdot \frac{1 - 2\lambda^n \cdot \cos. n\nu + \lambda^{2n}}{(1+\lambda^2)^n},$$

or, since $\cos. \nu = \cos. n\,(\pi + \varpi_1)$

$$r^{(2)}_{1} \ldots\ldots r^{(2)}_{n} = a^n \cdot \frac{1 - 2\lambda^n \cdot \cos. n(\pi + \varpi_1) + \lambda^{2n}}{(1+\lambda^2)^n} \cdot \ldots \left\{5,1\right\}.$$

As this case, however, is manifestly similar to that of $\left\{4,1\right\}$, we shall pursue it no farther.

The 6th of the equations, in page 9, offers, however, some results worthy of consideration. By treating it like the rest, it becomes

$$\frac{r^{(1)}_{1} \ldots\ldots r^{(1)}_{n}}{r^{(2)}_{1} \ldots\ldots r^{(2)}_{n}} = \frac{1 - 2\lambda^n \cdot \cos. n\varpi_1 + \lambda^{2n}}{1 - 2\lambda^n \cdot \cos. n(\pi + \varpi_1) + \lambda^{2n}} \cdot \ldots \left\{6,1\right\}.$$

1. When $\varpi_1 = 0$, it becomes

$$\frac{(1-\lambda^2)^2}{1-2\lambda^2 \cdot \cos.(n\varphi)+\lambda^{4n}}$$

If then, n be even, this is equal to unity, as it evidently ought, but if odd

$$\frac{f^{(1)} \ldots\ldots f^{(1)}}{f^{(2)} \ldots\ldots f^{(2)}} = \left(\frac{1-\lambda^2}{1+\lambda^2}\right)^2 = -\left(\tan.\frac{n\varphi}{2}\right)^2 \ldots\ldots \left\{6,2\right\}.$$

2. Let $\varphi = \frac{\pi}{3}$, and $n = 6m+1$, and we find

$$\frac{f^{(1)} \ldots\ldots f^{(1)}}{f^{(2)} \ldots\ldots f^{(2)}} = \left(\frac{1+\lambda^{2n}}{1-\lambda^{2n}}\right) \cdot \left(\frac{1-\lambda^2}{1+\lambda^2}\right) = \tan.\frac{n\varphi}{2} \cdot \operatorname{cotan}.\frac{3n\varphi}{2} \left\{6,3\right\}.$$

We come now to our 7th Equation, which will afford us results, more complicated indeed, yet equally interesting. By applying the same method of transformation to it, we shall find, (supposing $\varphi_1, \varphi_2, \ldots\ldots \varphi_n = \varphi + \frac{2(n-1)\pi}{n}$, to be written for φ, and $R_1, R_2, \ldots\ldots R_n$ to denote the resulting values of R)

$$R_1 \ldots\ldots R_n = a^n \cdot \frac{(1+\lambda^2)^n (1-e^2)^{\frac{n}{2}}}{\left\{1-2\lambda^2 \cdot \cos.n\varphi + \lambda^{4n}\right\}^{\frac{1}{2}} \cdot \left\{1-2\lambda^2 \cdot \cos.n(\pi+\varphi)+\lambda^{4n}\right\}^{\frac{1}{2}}}$$

$\left\{7,1\right\}$.

1. If n be even, $\cos.n\varphi_1 = \cos.n(\pi+\varphi_1)$ and, since $1-e^2 = \left\{\frac{1-\lambda^2}{1+\lambda^2}\right\}^2$, this becomes

$$R_1 \ldots\ldots R_n = a^n \cdot \frac{(1-\lambda^2)^n}{1-2\lambda^2 \cdot \cos.n\varphi_1+\lambda^{4n}} \ldots\ldots \left\{7,2\right\}.$$

2. If n be odd, $\cos.n\varphi_1 = -\cos.n(\pi+\varphi_1)$, whence

$$R_1 \ldots\ldots R_n = a^n \cdot \frac{(1-\lambda^2)^n}{\left\{1-2\lambda^2 \cdot \cos.n\varphi_1+\lambda^{4n}\right\}^{\frac{1}{2}} \cdot \left\{1+2\lambda^2 \cdot \cos.n\varphi_1+\lambda^{4n}\right\}^{\frac{1}{2}}}$$

$$= a^n \cdot \frac{(1-\lambda^2)^r}{\left\{1-2\lambda^{2n}(2\,.\,\cos.\,n\rho^2-1)+\lambda^{4n}\right\}^{\frac{1}{2}}}, \text{ or}$$

$$\underset{1}{\mathrm{R}}.....\underset{n}{\mathrm{R}} = a^n \cdot \frac{(1-\lambda^2)^r}{\left\{1-2\lambda^{2n}\,.\,\cos.\,2n\rho+\lambda^{4n}\right\}^{\frac{1}{2}}} \quad . \quad . \quad . \quad . \quad \left\{7,3\right\}.$$

Let $\underset{1}{\rho} = o$, or, let the extremity of one of the R lie in the principal vertex, If n be even

$$\underset{1}{\mathrm{R}}.....\underset{n}{\mathrm{R}} = a^n \cdot \frac{(1-\lambda^2)^r}{(1-\lambda^2)^r} = a^n \cdot \frac{(\sin.\,\alpha)^r}{(\sin.\,\frac{\pi}{n}\alpha)^r} \quad . \quad . \quad . \quad . \quad \left\{7,4\right\}.$$

If odd,

$$\underset{1}{\mathrm{R}}.....\underset{n}{\mathrm{R}} = a^n \cdot \frac{(1-\lambda^2)^r}{1-\lambda^{2n}} = a^n \cdot \frac{(\sin.\,\alpha)^r}{\sin.\,n\alpha} \quad . \quad . \quad . \quad . \quad . \quad \left\{7,5\right\}.$$

Let $\underset{1}{\rho} = \frac{\pi}{2}$, and $n = 4m + 2$, In this case, two out of the R are at right angles to the axis, and

$$\underset{1}{\mathrm{R}}.....\underset{n}{\mathrm{R}} = a^n \cdot \frac{(1-\lambda^2)^r}{(1+\lambda^2)^r} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \left\{7,6\right\}.$$

Again, let *one only* of the R be perpendicular to the axis, and

$$\underset{1}{\mathrm{R}}.....\underset{n}{\mathrm{R}} = a^n \cdot \frac{(1-\lambda^2)^r}{1+\lambda^{2n}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \left\{7,7\right\}.$$

Here n is of course odd.

Next, let one of the R be inclined at an angle $\frac{\pi}{4}$ to the axis. If $n = 4m + 2$,

$$\underset{1}{\mathrm{R}}.....\underset{n}{\mathrm{R}} = a^n \cdot \frac{(1-\lambda^2)^r}{1+\lambda^{2n}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \left\{7,8\right\},$$

and it is curious to observe, that this expression is the same function of a, λ, n, as that of $\left\{7,7\right\}$.

If n be of the form $2m + 1$,

$$\underset{1}{\mathrm{R}}.....\underset{n}{\mathrm{R}} = a^n \cdot \frac{(1-\lambda^2)^r}{\sqrt{1+\lambda^{2n}}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \left\{7,9\right\}.$$

Lastly, let n be of the form $6m + 2$, and $\underset{1}{\rho} = \frac{\pi}{3}$, then

$$\underset{1}{R}.....\underset{n}{R} = a^n \cdot \frac{(1-\lambda^2)^n (1-\lambda^n)}{(1-\lambda^{2n})} \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \left\{7,10\right\};$$

but, if $n = 6m + 1$,

$$\underset{1}{R}.....\underset{n}{R} = a^n \cdot \frac{(1-\lambda^2)^n}{\sqrt{(1+\lambda^{2n}+\lambda^{4n})}} \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \left\{7,11\right\}.$$

These are always imaginary expressions when $e > 1$ and n odd. In fact, R, in the hyperbola, must be written

$$\frac{a\sqrt{e^2-1}}{\sqrt{e^2 \cdot \cos.\varphi^2 - 1}} \text{ instead of } \frac{a\sqrt{1-e^2}}{\sqrt{1-e^2 \cdot \cos.\varphi^2}}$$

now $\sqrt{e^2-1} = e \cdot \frac{1-\lambda'^2}{1+\lambda'^2}$. Thus, this expression, like the rest, is easily transformed, in functions of a, λ, λ', the λ' is now real, and the part involving λ will always be of the form $f(\lambda^m \pm \lambda^{-m})$, and therefore readily expressed in trigonometrical functions.

Before we proceed farther, it will be necessary to premise a transformation of COTES's formula, which we shall have occasion to make use of. It is as follows:

$$\left.\begin{array}{l} \text{sin. } (A+B) \cdot \text{sin. } (A-B) = 2^{2n-2} \cdot P \cdot Q, \text{ where} \\ P = \text{sin.}\left(\frac{A+B}{n}\right) \cdot \text{sin.}\left(\frac{\pi+(A+B)}{n}\right) \cdot \text{sin.}\left(\frac{2\pi+(A+B)}{n}\right) \cdot \cdot \cdot \cdot \cdot \\ \text{sin.}\left(\frac{(n-1)\pi+(A+B)}{n}\right) \\ Q = \text{sin.}\left(\frac{A-B}{n}\right) \cdot \text{sin.}\left(\frac{\pi+(A-B)}{n}\right) \cdot \text{sin.}\left(\frac{2\pi+(A-B)}{n}\right) \cdot \cdot \cdot \cdot \cdot \\ \text{sin.}\left(\frac{(n-1)\pi+(A-B)}{n}\right) \end{array}\right\} (a)$$

The demonstration is extremely simple,

$$1 - 2x^n \cdot \cos. a + x^{2n} = \left(1 - 2x \cdot \cos.\frac{a}{n} + x^2\right)\left(1 - 2x \cdot \cos.\frac{a+2\pi}{n} + x^2\right) \cdot \cdot \cdot \cdot \cdot \cdot \left(1 - 2x \cdot \cos.\frac{a+2(n-1)\pi}{n} + x^2\right),$$

or dividing by x^n

$$x^n + x^{-n} - 2 \cdot \cos. a = \left(x + x^{-1} - 2 \cdot \cos.\frac{a}{n}\right) \cdot \cdot \cdot \cdot \cdot \cdot \cdot$$

$\left(x + x^{-1} - 2 \cdot \cos. \frac{a+2(n-1)\pi}{n}\right)$.

Let $x + x^{-1} = 2 \cdot \cos. c$; then $x^n + x^{-n} = 2 \cdot \cos. nc$, and $\cos. nc - \cos. a = 2^{n-1} \left(\cos. c - \cos. \frac{a}{n}\right) \ldots\ldots \left(\cos. c - \cos. \frac{a+2(n-1)\pi}{n}\right)$, that is (by the formula $\cos. x - \cos. y = -2 \cdot \sin. \frac{x+y}{2} \cdot \sin. \frac{x-y}{2}$) $\cdot \sin. \left(\frac{a+nc}{2}\right) \cdot \sin. \left(\frac{a-nc}{2}\right) = 2^{2n-2}$

$\cdot \sin. \frac{1}{2}\left(\frac{a}{n} + c\right) \cdot \sin. \frac{1}{2}\left(\frac{a+2\pi}{n} + c\right)$. &c.

$\cdot \sin. \frac{1}{2}\left(\frac{a}{n} - c\right) \cdot \sin. \frac{1}{2}\left(\frac{a+2\pi}{n} - c\right)$. &c.

Let $\frac{a+nc}{2} = A + B$, and $\frac{a-nc}{2} = A - B$, and by substitution, the formula under consideration results.

This immediately gives the following

$$\left.\begin{array}{l} \cos. (A+B) \cdot \cos. (A-B) = 2^{2n-2} \cdot P \cdot Q, \text{ where} \\ P = \sin. \left\{\frac{\left(\frac{\pi}{2}\right) - (A+B)}{n}\right\} \cdot \sin. \left\{\frac{3\left(\frac{\pi}{2}\right) - (A+B)}{n}\right\} \ldots\ldots \\ \sin. \left\{\frac{(2n-1) \cdot \left(\frac{\pi}{2}\right) - (A+B)}{n}\right\} \\ Q = \sin. \left\{\frac{\left(\frac{\pi}{2}\right) - (A-B)}{n}\right\} \cdot \sin. \left\{\frac{3\left(\frac{\pi}{2}\right) - (A-B)}{n}\right\} \ldots\ldots \\ \sin. \left\{\frac{(2n-1)\left(\frac{\pi}{2}\right) - (A-B)}{n}\right\} \end{array}\right\} (b)$$

and also,

$$\left.\begin{array}{l} \cos. (A+B) \cdot \sin. (A-B) = 2^{2n-2} \cdot P \cdot Q, \text{ where} \\ P = \sin. \left\{\frac{\left(\frac{\pi}{2}\right) - (A+B)}{n}\right\} \cdot \sin. \left\{\frac{3\left(\frac{\pi}{2}\right) - (A+B)}{n}\right\} \ldots\ldots \\ \sin. \left\{\frac{(2n-1)\left(\frac{\pi}{2}\right) - (A+B)}{n}\right\} \\ Q = \sin. \left(\frac{A-B}{n}\right) \cdot \sin. \left(\frac{\pi+(A-B)}{n}\right) \ldots \sin. \left(\frac{(n-1)\pi+(A-B)}{n}\right). \end{array}\right\} (c)$$

Let $B = o$, and (a) gives

$$\sin. A = 2^{n-1} . \sin. \frac{A}{n} . \sin. \frac{\pi + A}{n} . \sin. \frac{2\pi + A}{n} \ldots \sin. \frac{(n-1)\pi + A}{n}. \quad (d)$$

If $A = \frac{\pi}{2}$, this becomes

$$1 = 2^{n-1} . \sin. \frac{\pi}{2n} . \sin. \frac{3\pi}{2n} . \sin. \frac{5\pi}{2n} \ldots\ldots \sin. \frac{(2n-1)\pi}{2n}. \quad (e)$$

(b) gives by making $B = o$,

$$\cos. A = 2^{n-1} . \sin. \frac{\left(\frac{\pi}{2}\right) - A}{n} . \sin. \frac{3\left(\frac{\pi}{2}\right) - A}{n} \ldots \sin. \frac{(2n-1)\left(\frac{\pi}{2}\right) - A}{n}. \quad (f)$$

If $A = \frac{\pi}{3}$, this gives

$$1 = 2^{n} . \sin. \frac{\pi}{6n} . \sin. \frac{7\pi}{6n} . \sin. \frac{13\pi}{6n} . \sin. \frac{19\pi}{6n} \ldots\ldots \sin. \frac{(6n-5)\pi}{6n}. \quad (g)$$

Equation (c) divided by (b) gives, (putting A, for $A - B$).

$$\tan. A = \frac{\sin. \frac{A}{n} . \sin. \frac{\pi + A}{n} . \sin. \frac{2\pi + A}{n} \ldots\ldots\ldots \sin. \frac{(n-1)\pi + A}{n}}{\sin. \left\{\frac{\left(\frac{\pi}{2}\right) - A}{n}\right\} . \sin. \left\{\frac{3\left(\frac{\pi}{2}\right) - A}{n}\right\} \ldots \sin. \left\{\frac{(2n-1)\left(\frac{\pi}{2}\right) - A}{n}\right\}}. \quad (h)$$

But, to return from this digression, let us take Equation $\{8\}$, and putting it into this form

$$\rho = \frac{2\rho . (1+\lambda^2)^n . \sin. \left(\frac{\pi}{2} - \psi\right)}{(1 - 2\lambda . \cos. \psi + \lambda^2)(1 - 2\lambda . \cos. \{\pi - \psi\} + \lambda^2)}$$

for ψ substitute each of a series of angles, n in number

$$\underset{1}{\psi}; \underset{1}{\psi} + \frac{\pi}{n}; \underset{1}{\psi} + \frac{2\pi}{n}; \ldots\ldots \underset{1}{\psi} + \frac{(n-1)\pi}{n},$$

and let $\underset{1}{\rho}, \underset{2}{\rho}, \ldots\ldots \underset{n}{\rho}$ be the resulting values of ρ.

The values of $\sin. \left(\frac{\pi}{2} - \psi\right)$ in an inverted order, are (if $\nu = - \left\{\underset{1}{\psi} + \frac{n-2}{n} . \left(\frac{\pi}{2}\right)\right\}$) $\sin. \nu$; $\sin. \left(\nu + \frac{\pi}{n}\right)$; $\sin. \left(\nu + \frac{2\pi}{n}\right)$; .... $\sin. \left(\nu + \frac{n-1}{n}\pi\right)$, and their product, $= \sin. \frac{n\nu}{n} . \sin. \frac{\pi + n\nu}{n}$ .... $\sin. \frac{(n-1)\pi + n\nu}{n} = \frac{\sin. n\nu}{2^{n-1}}$ (by Equation (d)) $= \frac{\sin. n\left(\frac{\pi}{2} + \underset{1}{\psi}\right)}{2^{n-1}}$.

Again, the values of ψ being $\underset{1}{\psi}, \ldots\ldots \underset{1}{\psi} + \frac{(n-1)\pi}{n}$, those of $\pi + \psi$, or $2\pi - (\pi - \psi)$ will be

$$\underset{1}{\psi} + \frac{n\pi}{n}, \underset{1}{\psi} + \frac{(n+1)\pi}{n}; \ldots\ldots \underset{1}{\psi} + \frac{(2n-1)\pi}{n}.$$

Now, $\cos. 2\pi - (\pi - \psi) = \cos. (\pi - \psi)$. Hence, the product of all the denominators of $\underset{1}{\rho}, \underset{2}{\rho}$, &c. will be $(1 - 2\lambda . \cos. \underset{1}{\psi} + \lambda^2)(1 - 2\lambda . \cos. (\underset{1}{\psi} + \frac{\pi}{n}) + \lambda^2) \ldots (1 - 2\lambda . \cos. (\underset{1}{\psi} + \frac{(n-1)\pi}{n}) + \lambda^2) . \cos. (\underset{1}{\psi} + \frac{\pi}{n}) + \lambda^2) \ldots (1 - 2\lambda . \cos. (\underset{1}{\psi} + \frac{(2n-1)\pi}{n}) + \lambda^2) =$, by Cotes's formula

$$1 - 2\lambda^{2n} . \cos. 2n \underset{1}{\psi} + \lambda^{4n}.$$

Thus we have, combining these separate processes,

$$\left.\begin{aligned} \underset{1}{\rho} . \underset{2}{\rho} \ldots . \underset{n}{\rho} &= 2a^n (1 - e^2)^n . (1 + \lambda^2)^{2n} . \frac{\sin. n\left(\frac{\pi}{2} + \underset{1}{\psi}\right)}{1 - 2\lambda^{2n} . \cos. 2n \underset{1}{\psi} + \lambda^{4n}} \\ &= 2p^n . \frac{(1+\lambda^2)^{2n} . \sin. n\left(\frac{\pi}{2} + \underset{1}{\psi}\right)}{1 - 2\lambda^{2n} . \cos. 2n \underset{1}{\psi} + \lambda^{4n}} = 2a^n . \frac{(1-\lambda^2)^{2n} . \sin. n\left(\frac{\pi}{2} + \underset{1}{\psi}\right)}{1 - 2\lambda^n . \cos. 2n \underset{1}{\psi} + \lambda^{4n}} \end{aligned}\right\} \{\quad\}$$

1. Let n be any number of the form $4m + 1$; then

$$\underset{1}{\rho} \ldots . \underset{n}{\rho} = 2p^n . \frac{(1+\lambda^2)^{2n} . \cos. n \underset{1}{\psi}}{1 - 2\lambda^{2n} . \cos. 2n \underset{1}{\psi} + \lambda^{4n}} \quad . \quad . \quad . \quad . \quad . \quad \{8,2\}^1.$$

If now $\underset{1}{\psi} = 0$, or one of the ρ coincide with the transverse axis,

$$\underset{1}{\rho} \ldots . \underset{n}{\rho} = \frac{2p^n (1+\lambda^2)^{2n}}{(1-\lambda^{2n})^2} = 2a^n . \frac{(1-\lambda^2)^{2n}}{(1-\lambda^{2n})^2} \quad . \quad . \quad . \quad . \quad . \quad \{8,3\}.$$

Let, next, $\underset{1}{\psi} = \frac{\pi}{4}$ $\{n$ continuing $= 4m + 1\}$ and,

$$\underset{n}{\rho} \ldots . \underset{n}{\rho} = \pm p^n \sqrt{2} . \frac{(1+\lambda^2)^{2n}}{1+\lambda^{4n}} \quad . \quad . \quad . \quad . \quad \{8,4\}.$$

In the parabola, $\lambda = 1$. Hence in this case,

$$\rho_1 \ldots \rho_n = \pm (2L)^n \cdot \sqrt{\tfrac{1}{2}} \quad \ldots \ldots \left\{8,5\right\}.$$

In fig. 2, let ASM be the axis of a parabola, BAC a tangent at the vertex, S the focus—bisect the angle BAM by AP, and draw $4m$ other lines AP_1, AP_2, AP_3, ... AP_n, so that if PA, PA, &c. be produced through A, this system of lines shall make equal angles around A, then, neglecting the sign

$$AP_1 \cdot AP_2 \ldots\ldots AP_n = (2L)^n \cdot \sqrt{\tfrac{1}{2}}.$$

If $n = 4m + 3$, the resulting value of $\rho_1 \ldots \rho_n$ is of the same form as $\left\{8,2\right\}$ with the exception of a different sign.

If n be of the form $4m$, or $4m + 2$,

$$\rho_1 \ldots\ldots \rho_n = \pm \frac{2a^n (1-\lambda^2)^{2n} \cdot \sin. n\psi_1}{1-2\lambda^{2n} \cdot \cos. 2n\psi_1 + \lambda^{4n}} \quad \ldots \ldots \left\{8,6\right\},$$

where the sign +, or −, is to be used, according as n is of the former, or latter form.

When $n = 4m + 2$, if $\psi_1 = \frac{\pi}{4}$, this becomes

$$\rho_1 \ldots\ldots \rho_n = \pm 2p^n \cdot \frac{(1+\lambda^2)^{2n}}{(1+\lambda^{2n})^2} \quad \ldots \ldots \left\{8,7\right\},$$

and when $\lambda = 1$.

$$\rho_1 \ldots\ldots \rho_n = \pm \frac{(2L)^n}{2} \quad \ldots \ldots \left\{8,8\right\}.$$

Thus, in the last mentioned construction, if the number of lines be $4m + 2$, instead of $4m + 1$

$$AP_1 \cdot AP_2 \ldots\ldots AP_n = \frac{(2L)^n}{2}.$$

The ninth of our primitive equations gives, if the angles

ϖ_1; $\varpi_2 = \varpi_1 + \frac{2\pi}{n}$; .... $\varpi_n = \varpi_1 + \frac{2(n-1)\pi}{n}$, be written for ϖ, and for θ $\left\{\text{a function of } \varpi, \text{ given by the equation } \cot.\tfrac{1}{2}\theta = \frac{1+\lambda}{1-\lambda}.\tan.\tfrac{1}{2}\varpi.\right\}$ be put θ_1; .... θ_n, the results of that substitution

$$\cos.\theta_1 . \cos.\theta_2 \ldots \cos.\theta_n = e^{-n} . \left(\frac{\lambda}{\lambda'}\right)^n . \frac{1-2\lambda^n . \cos.n\varpi_1 + \lambda^{2n}}{1-2\lambda^n . \cos.n\varpi_1 + \lambda^{2n}} . \{9,1\}.$$

If $\varpi_1 = o$, whatever be n,

$$\cos.\theta_1 \ldots \cos.\theta_n = e^{-n} . \left(\frac{\lambda}{\lambda'}\right)^n . \left(\frac{1-\lambda'^n}{1-\lambda^n}\right)^2 = e^{-n} . \left\{\frac{\lambda'^{\frac{n}{2}} - \lambda'^{-\frac{n}{2}}}{\lambda^{\frac{n}{2}} - \lambda^{-\frac{n}{2}}}\right\}^2 . \{9,2\}.$$

If $n = (2m+1)\ \frac{\pi}{\varpi_1}$,

$$\cos.\theta_1 .... \cos.\theta_n = e^{-n} . \left\{\frac{\lambda'^{\frac{n}{2}} + \lambda'^{-\frac{n}{2}}}{\lambda^{\frac{n}{2}} + \lambda^{-\frac{n}{2}}}\right\}^2 \quad . \quad . \quad . \quad . \quad . \quad \{9,3\}.$$

If $n = (2m+1) . \frac{\left(\frac{\pi}{2}\right)}{\varpi_1}$,

$$\cos.\theta_1 .... \cos.\theta_n = e^{-n} . \frac{\lambda'^n + \lambda'^{-n}}{\lambda^n + \lambda^{-n}} \quad . \quad . \quad . \quad . \quad . \quad . \quad \{9,4\}.$$

If $n = (6m+1) . \frac{\left(\frac{\pi}{3}\right)}{\varpi_1}$;

$$\cos.\theta_1 .... \cos.\theta_n = e^{-n} . \left(\frac{\lambda^{\frac{n}{2}} + \lambda^{-\frac{n}{2}}}{\lambda'^{\frac{n}{2}} + \lambda'^{-\frac{n}{2}}}\right) . \left(\frac{\lambda'^{\frac{3n}{2}} - \lambda'^{-\frac{3n}{2}}}{\lambda^{\frac{3n}{2}} + \lambda^{-\frac{3n}{2}}}\right) \{9,5\}.$$

If $n = (6m+2) . \frac{\left(\frac{\pi}{3}\right)}{\varpi_1}$,

$$\cos.\theta_1 .... \cos.\theta_n = e^{-n} . \left(\frac{\lambda^{\frac{n}{2}} - \lambda^{-\frac{n}{2}}}{\lambda'^{\frac{n}{2}} - \lambda'^{-\frac{n}{2}}}\right) . \left(\frac{\lambda'^{\frac{3n}{2}} - \lambda'^{-\frac{3n}{2}}}{\lambda^{\frac{3n}{2}} - \lambda^{-\frac{3n}{2}}}\right) \{9,6\}.$$

These theorems, however simple their algebraic expressions, it must immediately be seen, become for the most part complicated and unintelligible when geometrically enunciated. They are indeed (if we may in any case be allowed to consider a curve as unidentified with its equation) properties rather of the equations of the conic sections, than of the curves themselves,—of a limited number of disjoined points determined according to a certain law, rather than a series of consecutive ones composing a line.

JOHN F. W. HERSCHEL.

Slough, Oct. 6, 1812.

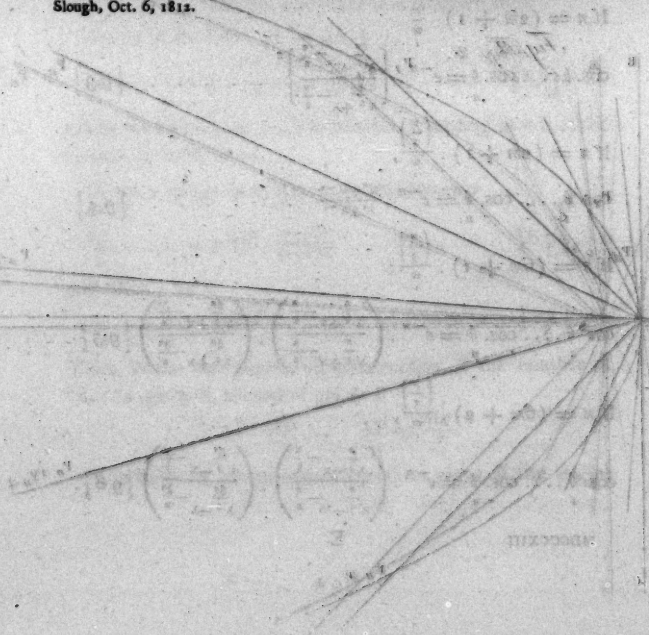


Fig. 1.

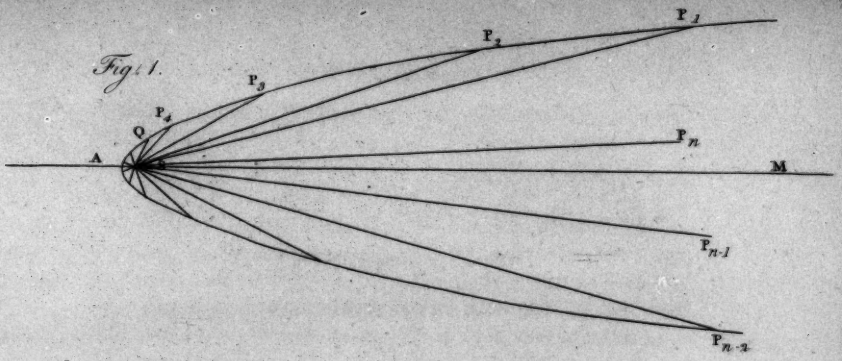
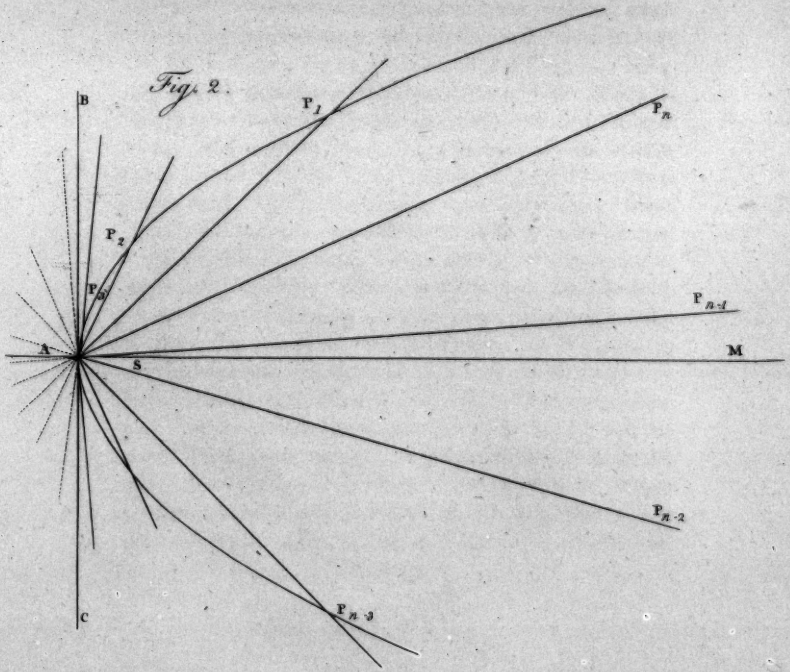


Fig. 2.



III. *Observation of the Summer Solstice, 1812, at the Royal Observatory.* *By* John Pond, *Esq. Astronomer Royal, F. R. S.*

Read November 12, 1812.

As it is intended that a minute description of the mural circle lately erected at the Royal Observatory, when completely finished, shall be laid before the Royal Society, I think it unnecessary to accompany this communication with any other remarks on its construction, than such as are absolutely necessary to render the annexed observations intelligible; being only anxious to take an early opportunity of transmitting the result of the observations of the sun, made at the last summer solstice. For, notwithstanding the instrument was at that time in a very unfinished and imperfect state, I have reason to think, that the observations made with it were much more exact than could have been made with any other instrument hitherto constructed: the uncertainty of the result, as far as the instrument itself is concerned, does not, I believe, exceed a small fraction of a second; but I think it necessary to offer a few remarks on the elements of the computation, by which the result is obtained.

The distance of the sun from the pole at the moment of the solstice, may either be considered as a simple arc, or as composed of two others, namely, the distance of the sun from the zenith, and the distance of the zenith from the pole. From the construction of instruments which take their point of departure from the position of a plumb-line or level, it is a general

method to measure these two arcs separately; that is to say, the zenith distance of the sun is considered as the immediate object of investigation, and the remaining arc, or as it is usually termed, the co-latitude of the place, (the knowledge of which is presumed) is added to complete the polar distance. But in whatever way we consider the subject, it is evident that the sole object of the practical astronomer is to obtain by some mechanical means the measure of this total arc.

The mural circle at Greenwich has neither level nor plumb-line, nor do I conceive that the least advantage could be derived from the application of either: its principle enables the observer to determine this total arc without any intermediate or zenith point, hence the co-latitude, the knowledge of which is so essential from the construction of other instruments, is in this case rather a question of curiosity than of absolute necessity.

I find it, however, convenient (for reasons which I hope to have an opportunity of stating more at large in a future Paper) to assume an intermediate point, which I call the zenith point, without being at all anxious to know whether it is really so or not; because I find myself possessed of the means of determining the position of this *imaginary* point of departure, on the instrument, to within the tenth of a second, a degree of precision, which I apprehend no level or plumb-line can ever be expected to equal.

From this point of departure, I measure the distance of the sun to the southward, and of the pole to the northward, and the sum of these two measures is evidently the north polar distance of the sun, which in every method is the ultimate object to be attained.

I have, as an example, annexed a computation of the same

solstice obtained by direct measurement, from the pole, without the aid of the intermediate point above mentioned; and it will be seen that the results do not in this case differ above a quarter of a second from each other.

There is indeed no other difference between these two methods but that, in the former case, the part of the arc Z P is obtained rather more accurately, by a great number of observations both before and after the solstice, than could be done in the short interval of time in which the solstice itself is observed.

By sixty observations of γ draconis, of which only three differ so much as 1″ from the mean, it appears that the zenith point which I have assumed is 2′, 18″,64, south of the mean position of γ draconis for the beginning of the year 1812, which is the same quantity that is found by the observations with the zenith sector, 1811.

Mr. TROUGHTON is now occupied in making a zenith sector upon a new and very simple principle, with which I have no doubt that this distance may be determined with a much greater degree of precision.

Astronomers will immediately perceive that this arc, however accurately it may be mechanically determined, must inevitably be subject to whatever uncertainty still exists upon the question of astronomical refractions; the instrument not having been erected long enough to remove this uncertainty, I have for the present employed Dr. BRADLEY's refractions, such as they have been used for many years in this Observatory. Such alterations in this part of the calculation may easily be made in future, as the advanced state of the science may require.

1812	Bar.	Ther. in.	Ther out	Ref.		Observations as given by the Instrument.	Position of the Zero Point, or Equation, to be applied to obtain the apparent N. P. D.	Equation to reduce the observed N. P. D. to Zenith Distance, or Position of Point on the Circle.	Semi-diameter of ⊙ 1′ greater than in the Nautical Almanack.	Reduction to the Solstice.	Solsticial Zenith. Distance with Parallax.	N. P. D. deduced by direct measurement from Polaris.
June				′ ″								
12	29,94	64	70	0,30,3	⊙ UL	66,33,33,0	12,95	38,31,34,10	15,47,2	0,17,15,4	28, 1, 1,0	66,32,21,4
14	29,76	63	71	0,29,4	⊙ UL	66,26,48,5	12,95	34,10	15,47,2	10,32,4	0,58,6	18,9
18	29,7	58	62	0,29,6	⊙ UL	66,18,20,2	12,95	34,10	15,46,8	2, 2,6	0,59,9	20,2
19	29,31	59	61	0,29,7	⊙ LL	65,48,44,6	10,04	38,31,31,20	15,46,8	0,57,0	0,59,3	19,9
20	29,28	57	60½	0,29,2	⊙ UL	66,16,31,4	10,04	31,20	15,46,8	0,16,3	0,59,9	20,5
23	29,78	56	61	0,30,4	⊙ LL	66,48,43,5	23,59	38,31,44,74	15,46,6	0,42,7	0,59,7	21,3
24	29,88	58	62	0,29,8	⊙ UL	66,18,11,3	23,59	44,74	15,46,6	1,41,1	1, 1,9	23,3
25	29,86	58	65	0,30,4	⊙ LL	66,51, 5,5	23,59	44,74	15,46,6	3, 4,2	1, 0,4	21,8
27	29,81	56	58	0,29,7	⊙ UL	66,23,33,5	23,59	44,74	15,46,6	7, 4,4	1, 0,7	22,0
28	29,78	54	54	0,30,7	⊙ LL	66,57,41,5	23,59	44,74	15,46,6	9,41,4	0,59,5	20,8
29	30,05	58	64	0,30,1	⊙ UL	66,29,11,4	23,59	44,74	15,46,6	12,43,0	1, 0,2	21,7
30	29,90	58	63	0,30,7	⊙ LL	67, 4, 9,5	23,59	44,74	15,46,6	16, 8,9	1, 0,1	21,4

Mean of 12 Observations	28, 1, 0,10	66,32,21,10
Nutation—8″, 4 Parallax 4″,0	— 12,40	— 12,40
	28, 0,47,70	
Z. P. determined by 30 observations of Polaris above, and 30 below	38,31,21,15	
Z. P + ⊙ Z or N. P. D.	66,32, 8,85	66,32, 8,70
Solsticial Declination	23,27,51,15	23,27,51,30
Correction for ⊙'s Latitude	+, 0,95	+, 0,95
Mean Obliquity at Summer Solstice	23,27,52,10	23,27,52,25

Subsequent observations gave the arc Z. P. rather greater than here assumed; but as I attribute this to a change in the refraction arising from a colder temperature, I take the arc as it was measured at the Summer Solstice.

This result may at any future time be rendered more accurate, if it should be found that the arc Z. P. has not been rightly determined; and in this consists the great advantage of the intermediate point Z., that the arc P. Z. may be determined more and more accurately, almost without limit, the only unalterable error resting on the determination of ⊙ Z.

IV. *Observations relative to the near and distant Sight of different Persons.* By James Ware, *Esq. F. R. S.*

Read November 19, 1812.

THE fact that near sightedness most commonly commences at an early period of life, and distant sightedness generally at an advanced age, is universally admitted. Exceptions, however, to these rules so frequently occur, that I flatter myself a brief statement of some of the coincident circumstances, attendant on these different imperfections in vision, may not be found wholly undeserving the attention of the Royal Society. Near sightedness usually comes on between the ages of ten and eighteen. The discovery of it most commonly arises from accident; and, at first, the inconvenience it occasions is so little, that it is not improbable the imperfection would remain altogether unnoticed, if a comparison were not instituted with the sight of others, or if the experiment were not made of looking through a concave glass. Among persons in the inferior stations of society, means are rarely resorted to for correcting slight defects of this nature; and, indeed, I have reason to believe the imperfection in such people is not unfrequently overcome by the increased exertions that are made by the eye to distinguish distant objects. This, however, is not the case, in the present day, with persons in the higher ranks of life. When these discover that their discernment of distant objects is less quick or less correct than that of others,

though the difference may be very slight, influenced perhaps by fashion more than by necessity, they immediately have recourse to a concave glass; the natural consequence of which is, that their eyes in a short time become so fixed in the state requiring its assistance, that the recovery of distant vision is rendered afterwards extremely difficult, if not quite impossible. With regard to the proportion between the number of near sighted persons in the different ranks of society, I have taken pains to obtain satisfactory information, by making inquiry in those places where a large number in these several classes are associated together. I have inquired, for instance, of the surgeons of the three regiments of foot guards, which consist of nearly ten thousand men; and the result has been, that near sightedness, among the privates, is almost utterly unknown. Not half a dozen men have been discharged, nor half a dozen recruits rejected, on account of this imperfection, in the space of nearly twenty years: and yet many parts of a soldier's duty require him to have a tolerably correct view of distant objects; as of the movements of the fugleman in exercise, and of the bull's eye when shooting at the target; the want of which might furnish a plausible apology for a skulker to skreen himself from duty, or to get his discharge from the service. I pursued my inquiries at the military school at Chelsea, where there are thirteen hundred children, and I found that the complaint of near sightedness had never been made among them until I mentioned it; and there were then only three who experienced the least inconvenience from it. After this, I inquired at several of the colleges in Oxford and Cambridge; and, though there is a great diversity in the number of students who make use of glasses in the various

colleges, they are used by a considerable proportion of the whole number in both Universities; and, in one college in Oxford, I have a list of the names of not less than thirty-two out of one hundred and twenty-seven, who wore either a hand glass or spectacles, between the years 1803 and 1807. It is not improbable, that some of these were induced to do it solely because the practice was fashionable; but, I believe, the number of such is inconsiderable, when compared with that of those whose sight received some small assistance from them, though this assistance could have been dispensed with, without inconvenience, if the practice had not been introduced. The misfortune resulting from the use of concave glasses is this, that the near sightedness is not only fixed by it, but a habit of inquiry is induced with regard to the extreme perfection of vision; and, in consequence of this, frequent changes are made for glasses that are more and more concave, until at length the near sightedness becomes so considerable, as to be rendered seriously inconvenient and afflicting. It should be remembered, that, for common purposes, every near sighted eye can see with nearly equal accuracy through two glasses, one of which is one number deeper than the other; and though the sight be in a slight degree more assisted by the deepest of these than by the other, yet on its being first used, the deepest number always occasions an uneasy sensation, as if the eye was strained. If, therefore, the glass that is most concave be at first employed, the eye, in a little time, will be accommodated to it, and then a glass one number deeper may be used with similar advantage to the sight; and if the wish for enjoying the most perfect vision be indulged, this glass may soon be changed for one that is a number still deeper, and so

in succession, until at length it will be difficult to obtain a glass sufficiently concave to afford the assistance that the eye requires.*

Although near sightedness is in general gradual in its progress, instances occasionally occur of its existence, in a considerable degree, even in children; in whom it is sometimes discovered almost as soon as they begin to take notice of the objects around them. This may be occasioned by some degree of opacity in the transparent parts of the eye; but such a cause of near sightedness is easily discovered by an examination, and is quite different from that state of the eye to which the term myopia, or near sightedness, is usually applied; by which is simply meant, too great a convexity either in the cornea or in the crystalline, in proportion to the distance of these parts from the retina. In such cases of extreme near sightedness in children, it is sometimes necessary to deviate from a rule, which in slighter cases I always follow, of discouraging the use of spectacles; since without their assistance, it would be impossible for them to prosecute their learning with ease or convenience.

Extreme near sightedness is sometimes occasioned by an evident change in the spherical figure of the cornea, and its assumption of a conical shape. This morbid state of the cornea is not only productive of near sightedness, but when the

* I have observed, that most of the near sighted persons, with whom I have had an opportunity of conversing, have had the right eye more near sighted than the left; and I think it not improbable, that this difference between the two eyes has been occasioned by the habit of using a single concave hand-glass; which, being most commonly applied to the right eye, contributes, agreeably to the remark abovementioned, to render this eye more near sighted than the other.

projection is considerable, vision is so much confused, that it affords little or no service, and cannot be amended by any glass. The cornea, in most of these cases, is preternaturally thin, and not unfrequently it is accompanied with symptoms of general debility; under which last circumstance chalybeate medicines, and bracing applications to the eye, have been found to afford considerable benefit.

Near sightedness, to an alarming degree, has sometimes attacked young persons suddenly. A remarkable case of this kind came under my notice a few years ago in a young gentleman at Westminster school, who had been attended by Sir GEORGE BAKER and Mr. SUTHERLAND, on account of a variety of anomalous nervous symptoms. These had wholly left him before I was consulted; and the consultation with me was solely for the purpose of determining whether he might be permitted to make use of concave glasses, and to return to the business of the school. The patient's health at that time not being perfectly restored, it was thought adviseable to send him for a few weeks into the country, and to postpone the use of glasses. This advice was followed; but in ten days the afflicted youth died suddenly. No anatomical examination of the head was permitted by the relatives. It seems, however, probable, that the near sightedness, as well as the previous indisposition, no less than the death of the patient, were occasioned by the pressure of a morbid substance of some kind or other on the source of the nerves in the brain.

Near sightedness is seldom alike in the two eyes, and a few cases have come under my observation, in which one eye of

the same person has had a near, and the other a distant sight.

It has been said by Dr. PORTERFIELD,* that the pupils of near sighted persons are more dilated than those of others. This, however, does not accord with the observations I have made in such cases.

It has also been commonly believed, that the size of the pupil is influenced by the distance of the object to which the attention is directed, this aperture being enlarged when the object is far off, and becoming more and more contracted as it is brought near. But though the activity of the fibres of the iris is sometimes sufficient to be visibly influenced by this circumstance, yet in the greater number even of those cases where the dilatation and contraction of the pupil are powerfully influenced by a difference in the strength of the light, the distance of the object considered alone, produces so little effect upon it, as to be scarcely perceived. That it has, however, in general, some degree of power on the pupil is highly probable; and an extraordinary instance of this kind exists, at the present time, in a lady between thirty and forty years of age, the pupil of whose right eye, when she is not engaged in reading, or in working with her needle, is always dilated very nearly to the rim of the cornea; but whenever she looks at a small object, nine inches from the eye, it contracts, within less than a minute, to a size nearly as small as the head of a pin. Her left pupil is not affected like the right; but in every degree of light and distance, it is contracted rather more than is usual in other persons. The vision is not precisely alike in the two eyes; the right eye being in a small degree near

* Treatise on the Eye and the Manner of Vision, Vol. II. p. 38.

sighted, and receiving assistance from the first number of a concave glass, whereas the left eye derives no benefit from it. This remarkable dilatation of the pupil of the right eye was first noticed about twenty years ago, and a variety of remedies have been employed at different times with a view to correct it; but none of them have made any alteration. It should be mentioned, that, in order to produce the contraction of the pupil, the object looked at must be placed exactly nine inches from the eye; and if it be brought nearer, it has no more power to produce the contraction than if it were placed at a remoter distance. It should also be mentioned, that the continuance of the contraction of the pupil depends, in some degree, on the state of the lady's health; since, though its contraction never remains long after the attention is withdrawn from a near object, yet whenever she is debilitated by a temporary ailment, the contraction is of much shorter duration than when her health is entire.*

Dr. WELLS, in his ingenious paper, published in the Second Part of the Transactions of the Royal Society for the year

* Several instances have come under my notice, in which the pupil of one eye has become dilated to a great degree, and has been incapable of contracting on an increase of light, whilst the pupil of the other eye has remained of its natural size. In some of these, the eye with the dilated pupil has been totally deprived of sight, the disorder answering to that of a perfect *amaurosis*; but in others, the dilatation of the pupil has only occasioned an inability to distinguish minute objects. Reading has been accomplished with difficulty, and convex glasses have afforded very little assistance. Though objects at a distance were seen with less inconvenience, than those that were near, these also appeared to the affected eye much less distinct than to the other. Most of the persons to whom I allude had been debilitated, by fatigue or anxiety, before the imperfection was discovered in the sight; and in some it had been preceded by affections of the stomach and alimentary canal.

1811, has taken pains to ascertain, whether the power by which the eye is adjusted to see at different distances, depends in any degree on the faculty in the pupil of dilating and contracting; and whether its fixed dilatation has any influence in preventing an accurate view of near objects. This last mentioned effect Dr. WELLS relates to have taken place remarkably in the case of Dr. CUTTING, whose pupil being fixed in a dilated state by the action of the extract of belladonna, perfect vision of a near object was removed, as the dilatation advanced, from six inches (which was the nearest distance at which Dr. CUTTING could distinctly see the image of the flame of a candle reflected from the bulb of a small thermometer,) to seven inches in thirty minutes, and to three feet and a half in three quarters of an hour. My eldest son, who has a very extensive range of vision, has made a similar experiment on his right eye with a similar result. Previous to the application of the belladonna, he could bring the apparent lines on an optometer (like that improved by Dr. YOUNG from the invention of Dr. PORTERFIELD, and described in the Philosophical Transactions for the year 1800) to meet at four inches from the eye; and, by directing his attention to a more distant point, he could prevent them from meeting till they were seven inches from the eye, after which they continued apparently united the whole length of the optometer, which was twelve inches.* He could see the image of a candle

* The two lines that are perceived on looking through the slits of an optometer, cross each other precisely in the point from whence the rays of light diverge in order to be brought to a focus on the retina. And their apparent union before and after this point is occasioned by the unavoidable thickness of the line drawn on the optometer.

reflected from the bulb of a small thermometer, five-sixteenths of an inch in diameter, at the distance of three inches and three quarters from the eye; and he could also see the same image at the distance of two feet seven inches. The belladonna produced a conspicuous dilatation of the pupil in less than an hour; after which, on viewing the apparent lines on the optometer, he was unable to make them meet at a nearer distance than seven inches, or to gain a distinct image of the candle reflected by the bulb of the thermometer nearer than this distance; but he could discern it at two feet ten inches from the eye, which was three inches further than he was able to see it, before the belladonna was applied. During the time of the experiment on the right eye, the left eye possessed its usual range of vision, but the sight, when both eyes were open, was rather confused, in consequence of the unequal foci of the two eyes; and it did not become clear until the pupil of the right eye recovered its usual power of contracting, which power was not acquired till the third day after the application of the belladonna.

It is remarkable that a different effect is sometimes produced on a near sighted eye by the application of the belladonna, from that which it has on an eye that enjoys a distant sight. Dr. Wells made an experiment of this kind on a friend of his, who was near sighted; and he informs us, in the paper above referred to, that in this instance, the nearest point of perfect vision was moved forwards during the dilatation of the pupil, whilst its remote point remained unaltered. I have made a similar experiment on the eyes of several such persons; and though in two of these the result appeared to be similar to that which has been mentioned by Dr. Wells, yet,

in the greater number, their sight, like that of those who were not myopic, has become more distant as the pupil became more dilated.—In one gentleman, in whom the lines of the optometer appeared to meet at four inches and a quarter from the eye, the pupil, in half an hour after the application of the belladonna, became completely dilated, and in consequence of this the sight at first was confused; but both on that day, and for two days afterwards, it was evidently more distant, and the apparent lines on the optometer could not be made to meet nearer than seven inches from the eye.—In a young lady, seventeen years of age, whose right eye was so near sighted that the apparent lines on the optometer met at two inches and three quarters from the eye, these lines, when the pupil was dilated (which took place in a small degree in less than half an hour), could not be made to meet in less than three inches and a quarter; and on the following day, the pupil being more dilated, the lines did not meet till they were at the distance of nearly four inches.—In a third instance, viz. that of a lady forty-five years of age, who had been remarkably near sighted from her infancy, and for many years had used concave glasses of the fifteenth number, (which number is ground on each side, upon a tool the radius of which is only three inches,) the sight was become so confused in both eyes, that she saw nothing distinctly, and was unable to read letters, of the size that are used in the printed Transactions of the Royal Society, either with or without a glass. In this case, after the pupils had been dilated by the application of the belladonna, the sight was so much improved that she was able to read a print of the abovementioned size at the distance

of two inches with either eye. I do not insist, however, on the present case, because, though there was not any visible opacity in the crystalline, this sometimes exists in a small degree without being perceptible even to an attentive observer; and it may be doubted whether the amendment in the lady's vision, were not occasioned solely by the retraction of the iris from before a part of the crystalline that was not yet become opaque: it being well known that the outer part of this lens not unfrequently retains its transparency for some time after an opacity has commenced in the part that surrounds its centre.

It is evident, that near sightedness has no dependence on the greater or smaller degree of convexity possessed by the cornea, when this circumstance is considered alone; since the length of the axis of the eye from the cornea to the retina, and the greater or smaller degree of convexity in the crystalline humour, must be also regarded, before the distance of accurate vision can be determined.

It is no less evident, that near sightedness is not necessarily occasioned by a morbid protrusion of the whole eye; since some persons are born with eyes of this description, and others acquire the peculiarity, when further advanced in life, in consequence of a morbid accumulation of *adeps* at the bottom of the orbit, without either of them being more near sighted than those who are free from this imperfection.

I have seen many instances in which old persons, who have been long accustomed to use convex glasses of considerable power, have recovered their former sight at the advanced age of eighty or ninety years, and have then had no further need of them. Dr. PORTERFIELD was of opinion that in such cases

the amendment is occasioned by a decay of *adeps* at the bottom of the orbit; in consequence of which the eye, from a want of the usual support behind, is brought, by the pressure of the muscles on its sides, into a kind of oval figure, in which state the retina is removed to its due focal distance from the flattened cornea. But if a morbid absorption of *adeps* at the bottom of the orbit were sufficient to restore the presbyopic to a good sight, it might be expected, that a morbid accumulation of *adeps* in this part would produce a presbyopic or distant sight. This, however, has not happened in any of the cases that have come under my notice. On the contrary, in some such persons a degree of near sightedness has been induced by the accumulation; and in others the sight, with regard to distance, has not been affected by it. It appears to me more probable, that this remarkable revolution in the sight of old persons is occasioned by an absorption of part of the vitreous humour; in consequence of which, the sides of the sclerotica are pressed inward, and the axis of the eye, by this lateral pressure, is proportionably lengthened. An alteration of this kind is also sufficient to explain the reason, why such aged persons retain the power of distinguishing objects at a distance, at the same time that they recover the faculty of seeing those that are near; since the lengthened axis of the eye leaves the power by which it is adjusted to see at different distances, precisely in the same state, in which it was before the lengthening of the axis took place.*

* Dr. YOUNG, in the paper to which I alluded in page 38, has described a great number of ingenious experiments devised by him, to shew that the faculty of seeing at different distances is produced by a power in the crystalline humour, to become more or less convex, according as the object is more or less distant from the eye.

Although old persons lose the power of distinguishing correctly near objects, and require for this purpose the aid of convex glasses, they usually retain the sight of those that are distant as well as when they were young. Instances, however, are not wanting of persons advanced in life, who require the aid of convex glasses to enable them to see near, as well as distant, objects. Dr. WELLS is one of these. He informs us, in the paper to which I have more than once adverted, that when twenty years younger, he was able, with his left eye, to bring to a focus on the retina, pencils of rays which flowed from every distance greater than seven inches from the cornea; but at the age of fifty-five, he required not only a convex glass of six inches focus, to enable him to bring to a point on the retina rays proceeding from an object seven inches from the eye, but likewise a convex glass of thirty-six inches focus, to enable him to bring to a point parallel rays.—There are also instances of young persons, who have so disproportionate a convexity of the cornea or crystalline, or of both, to the distance of these parts from the retina, that a glass of considerable convexity is required to enable them to see distinctly, not only near objects, but also those that are distant; and it is remarkable, that the same glass will enable many such persons to see both near and distant objects; thus proving that the defect in their sight is occasioned solely by too small a convexity in one of the parts abovementioned, and that it does not influence the power by which their eyes are adapted to see at distances variously remote. In this respect such persons differ from those who have had the crystalline humour removed by an operation; since the latter always require a glass to enable them to discern distant objects, different from

that which they use to see those that are near. This circumstance, in my apprehension, affords a convincing proof that the crystalline humour is indispensably necessary to enable the eye to see at different distances.—It is also worthy of remark, that persons who have had the crystalline humour removed, have less power to ascertain the distance of an object when they look through a convex glass, than when they view it without this assistance; in consequence of which such persons seldom make use of glasses when they are walking: and the inconvenience of glasses is particularly experienced when they descend a flight of steps, or pass over uneven ground.

Near sighted persons do not appear to possess the same extent of vision that is enjoyed by those who have a distant sight. Being near sighted, I have repeatedly endeavoured to ascertain my own range of vision: and I find, by examining the focus of my right eye through the abovementioned optometer, that I see two converging lines, which appear to meet, with very slight variations, at the distance of three inches from the eye; and no effort I am able to make can keep these lines united further than the distance of four inches and a quarter. They then separate, and continue to diverge. With my left eye, the lines do not appear to meet nearer than four inches, and they continue united as far as five inches and a quarter, after which they also separate and diverge; so that the range of distinct vision in me does not extend further than an inch and a quarter in either eye; and within these distances I always hold a book when I read.—I find also the following rule, for determining the concavity of the glass that is best adapted for near sighted persons, to be perfectly correct with respect to myself, and, I believe, it may be safely

adopted by those who, from distance or any other cause, are unable to suit themselves at the shop of an expert optician. The rule is this. Multiply the distance at which the person reads with ease, (which, with my left or best eye, is five inches,) by that at which he wishes to read, which may be said to be twelve inches; divide the product, sixty, by seven, the difference between the two, and it leaves nearly nine inches for the focus of the concave glass that shall produce the desired effect. This is the exact concavity of the glass that I am obliged to use, to enable me to read with ease; and it answers to that, sold under the name of No. 6; which, I am informed by Mr. BLUNT the optician, is a double concave glass, ground on a tool of eight inches radius on one side, and eleven inches on the other, the mean between which is very nearly nine inches. With a glass of this description I can read the smallest print, but to distinguish distant objects I am obliged to look through that, denominated No. 9, which is ground on a tool of nine inches radius on both sides. In this respect, my eye has varied from what it was a few years ago, when I was able to distinguish both near and distant objects correctly, through No. 8. This is ground to a radius of eight inches on one side, and six inches on the other, and with it I can still read a type like that in which the Transactions of the Royal Society are printed; but am unable to distinguish through it many distant objects, which I formerly used to see distinctly. —Hence it appears that my eyes have a confined range of distinct vision, extending only to an inch, or an inch and a quarter; and that they remain nearly in the same state in which they were many years ago with regard to near objects, but have lost a part of the power which they formerly

possessed, of adjusting themselves to distant ones. In this last respect, they differ from the eyes of those who have naturally a distant sight, since, as such persons advance in life, they usually retain the power of distinguishing distant objects, but lose that of seeing those that are near. It appears to militate also against the common observation, that as near sighted persons grow older they become less near sighted; since my eyes, on the contrary, are more near sighted, at the age of fifty-five, than they were at twenty-five, and I am now obliged to employ deeper concave glasses than I then used to see distant objects, though I am not able to see distinctly through them things that are near.

The alteration which has taken place in my range of vision, I have reason to believe, is not unusual. Dr. WELLS, in his paper on this subject, mentions the case of a gentleman, who, like me, was near sighted, and whose sight, as he advanced in life, had undergone a similar change.—The following is also an instance of this kind, that is still more remarkable. Mr. L. sixty-six years of age, who has spent a great part of his life in the West Indies, and whose sight, when he was young, enabled him to see both near and distant objects with great precision, began, at the age of forty, to experience a difficulty in reading and writing. He immediately procured convex spectacles of the first number sold by opticians, which glasses are usually ground to a focus of forty-six or forty-eight inches, and by the aid of these he continued to read and write with ease (distinguishing perfectly in the usual way all distant objects without them,) until he was fifty. At this time he first began to perceive an indistinctness in the appearance of things at a distance; and, on

trying with different glasses, he discovered that, by looking through a double concave glass of the sixth number, (which is ground to a radius of eight inches on one side and eleven inches on the other,) he was enabled to see distant objects distinctly. He has continued to use glasses of this description for the purpose of seeing distant objects from that time to the present; but is obliged to remove them whenever he reads, and still to employ the first number of a convex glass.—In this instance, a presbyopic was changed to a myopic sight, without any known efficient circumstance to produce it.—In the two following cases, a similar change took place; and in them it was attributable to known causes. A woman, about fifty years of age, of a full habit, who for several years had been obliged to make use of convex glasses, in order to read a small print, was seized with a dimness in the sight of the right eye, accompanied with a small degree of inflammation. The sight of the left eye having been long imperfect, this affection of the right eye occasioned a great depression of spirits. Recourse was necessarily had to copious evacuations, by means of which the inflammation and dimness of sight were soon removed; but afterwards the patient was much alarmed on finding that the spectacles she had been accustomed to wear, instead of affording their usual assistance, confused her sight. Upon this discovery, she was induced to look through her husband's glasses, which, in consequence of his being near sighted, were double concaves of the fifth number, and ground to a radius of eleven inches on each side. These did not assist her in looking at near objects, but by their aid she saw much more distinctly those that were distant; and, on attempting to read, nothing more was now necessary, than to bring

the book a little nearer to her, than she had been previously accustomed to place it.—The second case occurred in a patient about the same age, who, in the course of the last year, was attacked with an inflammation in both eyes. By the use of leaches and cooling medicines, it was speedily removed, and, afterwards, she was much gratified, by finding that the necessity for using glasses when she read, which had existed many years, was removed; and that she could see both near and distant objects correctly, without any extraneous help. The amendment in this lady's sight continued, however, only a few weeks; after which she was again obliged to use the same convex glasses in looking at small near objects, which she had used before her eyes became inflamed.—In addition to these cases, I beg leave to add the information I have received from an eminent mathematical instrument maker, about fifty years of age, who has long made use of convex glasses to assist his sight in reading. He tells me, that when he has been employed many hours together, for several successive days, in looking through a double microscope that magnifies twenty-eight times, (in order to enable him to mark the degrees on a small brass plate) he has afterwards been able, repeatedly, for a few weeks, to read without his glasses; but then the amendment gradually ceases, and he is soon obliged to return to the use of the same glasses that he had worn before.

In the instances that have been mentioned, the distant sightedness affected persons who were considerably advanced in life: but in the three that follow, a similar affection of the sight occurred in those that were young; and a like good effect was produced by the use of evacuating remedies. One

of these was a boy eight years old, who suddenly became presbyopic, and had repeatedly been punished at school, on account of his incorrect and defaced writing; the real cause of it, at that time, being unknown to his master. After the presbyopia had continued a fortnight, and different local applications had been used, without producing any sensibly good effects, the lad was cured by the application of leaches to the temples, and the administration of a few purgative medicines. The other instances occurred in two daughters of the same family. The eldest, twenty years of age, had never been able to do fine work, and for three years had been greatly assisted by convex spectacles. The youngest, a girl of fifteen, had become presbyopic about a year ago, and since that time had been obliged to use spectacles whenever she read, or worked with her needle. The young person, last mentioned, in the course of six weeks, (during which time she totally abstained from the use of glasses,) was completely relieved from the necessity of using them, by the application of two leaches to each temple twice in a week. The former, in the same space of time, experienced much relief from a similar treatment, but was still unable to do fine work without glasses, partly in consequence of the long continuance of the infirmity, and partly on account of her not having abstained with equal steadiness from the occasional use of them.

From the preceding statement, the following inferences may be deduced.

First; near sightedness is rarely observed in infants, or even in children under ten years of age. It affects the higher classes of society more than the lower: and the instances are few, if any, in which, if the use of concave glasses has been

adopted, increasing years have either removed or lessened this imperfection.

Secondly; though the usual effect of time on perfect eyes be that of inducing a necessity to make use of concave glasses, in order to see near objects distinctly, yet sometimes, even after the age of fifty, and after convex glasses have been used many years for this purpose, the eyes have not only ceased to derive benefit from them, when looking at near objects, but they have required concave glasses to enable them to distinguish, with precision, objects at a distance.

Thirdly; though the cause of this change be not always known, yet sometimes it has been induced by the use of evacuating remedies, particularly of leaches applied to the temples; and sometimes by looking through a microscope, for a continued length of time, in several successive days.

Fourthly; instances are not uncommon, in which persons, far advanced in life, (viz. between eighty and ninety,) whose eyes have been accustomed for a long time to the use of deeply convex glasses, when they have read or written, have ceased to derive benefit from these glasses, and they have become able, without any assistance, to see both near and distant objects almost as well as when they were young. Although it be not easy to ascertain the cause of this amended vision, it seems not improbable that it is occasioned by an absorption of part of the vitreous humour; in consequence of which the sides of the eye collapse, and its axis, from the cornea to the retina, is lengthened; by which alteration the length of this axis is brought into the same proportion to the flattened state of the cornea or crystalline, or both, which it had to these parts before the alteration took place.

V. *The Bakerian Lecture. On the elementary Particles of certain Crystals.* By William Hyde Wollaston, *M. D. Sec. R. S.*

Read November 26, 1812.

Among the known forms of crystallized bodies, there is no one common to a greater number of substances than the regular octohedron, and no one in which a corresponding difficulty has occurred with regard to determining which modification of its form is to be considered as primitive; since in all these substances the tetrahedron appears to have equal claim to be received as the original from which all their other modifications are to be derived.

The relations of these solids to each other is most distinctly exhibited to those who are not much conversant with crystallography, by assuming the tetrahedron as primitive, for this may immediately be converted into an octohedron by the removal of four smaller tetrahedrons from its solid angles. (Fig. 1.)

The substance which most readily admits of division by fracture into these forms is fluor spar; and there is no difficulty in obtaining a sufficient quantity for such experiments. But it is not, in fact, either the tetrahedron or the octohedron, which first presents itself as the apparent primitive form obtained by fracture.

If we form a plate of uniform thickness by two successive divisions of the spar, parallel to each other, we shall find the

plate divisible into prismatic rods, the section of which is a rhomb of 70° 32′ and 109° 28′ nearly; and if we again split these rods transversely, we shall obtain a number of regular acute rhomboids, all similar to each other, having their superficial angles 60° and 120°, and presenting an appearance of primitive molecule, from which all the other modifications of such crystals might very simply be derived. And we find, moreover, that the whole mass of fluor might be divided into, and conceived to consist of, these acute rhomboids alone, which may be put together so as to fit each other without any intervening vacuity.

But, since the solid thus obtained (as represented fig. 2.) may be again split by natural fractures at right angles to its axis (fig. 3.), so that a regular tetrahedron may be detached from each extremity, while the remaining portion assumes the form of a regular octohedron; and, since every rhomboid, that can be obtained, must admit of the same division into one octohedron and two tetrahedrons, the rhomboid can no longer be regarded as the primitive form; and since the parts into which it is divisible are dissimilar, we are left in doubt which of them is to have precedence as primitive.

In the examination of this question, whether we adopt the octohedron or the tetrahedron as the primitive form, since neither of them can fill space without leaving vacuities, there is a difficulty in conceiving any arrangement in which the particles will remain at rest: for, whether we suppose, with the Abbé HAÜY, that the particles are tetrahedral with octohedral cavities, or, on the contrary, octohedral particles regularly arranged with tetrahedral cavities, in each case the mutual contact of adjacent particles is only at their edges; and

although in such an arrangement it must be admitted that there may be an equilibrium, it is evidently unstable, and ill adapted to form the basis of any permanent crystal.

More than three years have now elapsed since a very simple explanation of this difficulty occurred to me. As in the course of that time I had not discovered it to be liable to any crystallographical objection, and as it had appeared satisfactory to various mathematical and philosophical friends to whom I proposed it, I had engaged to make this the subject of the Bakerian Lecture of the present year, hoping that some further speculations, connected with the same theory, might lead to more correct notions than are at present entertained of crystallization in general.

At the time when I made this engagement, I flattered myself that the conception might be deserving of attention from its novelty. But I have since found, that it is not altogether so new as I had then supposed it to be; for by the kindness of a friend, I have been referred to Dr. Hooke's Micrographia, in which is contained, most clearly, one essential part of the same theory.

However, since the office of a lecturer is properly to diffuse knowledge already acquired, rather than to make known new discoveries in science, and since these hints of Dr. Hooke have been totally overlooked, from having been thrown out at a time when crystallography, as a branch of science, was wholly unknown, and consequently not applied by him to the extent which they may now admit, I have no hesitation in treating the subject as I had before designed. And when I have so done, I shall quote the passage from Dr. Hooke, to shew how exactly the views which I have taken have, to a certain extent,

corresponded with his; and I shall hope that, by the assistance of such authority, they may meet with a more favourable reception.

The theory to which I here allude is this, that, with respect to fluor spar and such other substances as assume the octohedral and tetrahedral forms, all difficulty is removed by supposing the elementary particles to be perfect spheres, which by mutual attraction have assumed that arrangement which brings them as near to each other as possible.

The relative position of any number of equal balls in the same plane, when gently pressed together, forming equilateral triangles with each other (as represented perspectively in fig. 4.) is familiar to every one; and it is evident that, if balls so placed were cemented together, and the stratum thus formed were afterwards broken, the straight lines in which they would be disposed to separate would form angles of 60° with each other.

If a single ball were placed any where at rest upon the preceding stratum, it is evident that it would be in contact with three of the lower balls (as in fig. 5.), and that the lines joining the centres of four balls so in contact, or the planes touching their surfaces, would include a regular tetrahedron, having all its sides equilateral triangles.

The construction of an octohedron, by means of spheres alone, is as simple as that of the tetrahedron. For if four balls be placed in contact on the same plane in form of a square, then a single ball resting upon them in the centre, being in contact with each pair of balls, will present a triangular face rising from each side of the square, and the whole together will represent the superior apex of an octohedron; so that a

sixth ball similarly placed underneath the square will complete the octohedral group, fig. 6.

There is one observation with regard to these forms that will appear paradoxical, namely, that a structure which in this case was begun upon a square foundation, is really intrinsically the same as that which is begun upon the triangular basis. But if we lay the octohedral group, which consists of six balls, on one of its triangular sides, and consequently with an opposite triangular face uppermost, the two groups, consisting of three balls each, are then situated precisely as they would be found in two adjacent strata of the triangular arrangement. Hence in this position we may readily convert the octohedron into a regular tetrahedron, by addition of four more balls. (fig. 7.) One placed on the top of the three that are uppermost forms the apex; and if the triangular base, on which it rests, be enlarged by addition of three more balls regularly disposed around it, the entire group of ten balls will then be found to represent a regular tetrahedron.

For the purpose of representing the acute rhomboid, two balls must be applied at opposite sides of the smallest octohedral group, as in fig. 9. And if a greater number of balls be placed together, fig. 10 and 11, in the same form, then a complete tetrahedral group may be removed from each extremity, leaving a central octohedron, as may be seen in fig. 11, which corresponds to fig. 8.

The passage of Dr. Hooke, from which I shall quote so much as to connect the sense, is to be found at page 85 of his Micrographia.

"From this I shall proceed to a second considerable phe-
"nomenon, which these diamants (meaning thereby quartz

" crystals) exhibit, and that is the regularity of their figure " ——This I take to proceed from the most simple principle " that any kind of form can come from, next the globular; " for——I think I could make probable, that all these regular " figures arise only from three or four several positions or " postures of globular particles, and those the most plain and " obvious, and necessary conjunctions of such figured particles " that are possible——And this I have *ad oculum* demonstrated " with a company of bullets, so that there was not any regu- " lar figure which I have hitherto met withal of any of those " bodies that I have above named, that I could not with the " composition of bullets or globules imitate almost by shaking " them together.

" Thus, for instance, we find that globular bullets will of " themselves, if put on an inclining plain so that they may " run together, naturally run into a triangular order compos- " ing all the variety of figures that can be imagined out of " equilateral triangles, and such you will find upon trial all the " surfaces of alum to be composed of——

" —nor does it hold only in superficies, but in solidity also; " for it's obvious that a fourth globule laid upon the third in " this texture composes a regular tetrahedron, which is a very " usual figure of the crystals of alum. And there is no one " figure into which alum is observed to be crystallized, but " may by this texture of globules be imitated, and by no " other."

It does not appear in what manner this most ingenious philosopher thought of applying this doctrine to the formation of quartz crystal, of vitriol, of salt-petre, &c. which he names. This remains among the many hints which the peculiar jealousy

of his temper left unintelligible at the time they were written, and which, notwithstanding his indefatigable industry, were subsequently lost to the public, for want of being fully developed.

We have seen, that by due application of spheres to each other, all the most simple forms of one species of crystal will be produced, and it is needless to pursue any other modifications of the same form, which must result from a series of decrements produced according to known laws.

Since then the simplest arrangement of the most simple solid that can be imagined, affords so complete a solution of one of the most difficult questions in crystallography, we are naturally led to inquire what forms would probably occur from the union of other solids most nearly allied to the sphere. And it will appear that by the supposition of elementary particles that are spheroidical, we may frame conjectures as to the origin of other angular solids well known to crystallographers.

The obtuse Rhomboid.

If we suppose the axis of our elementary spheroid to be its shortest dimension, a class of solids will be formed which are numerous in crystallography. It has been remarked above, that by the natural grouping of spherical particles, fig. 10, one resulting solid is an acute rhomboid, similar to that of fig. 2, having certain determinate angles, and its greatest dimension in the direction of its axis. Now, if other particles having the same relative arrangement be supposed to have the form of oblate spheroids, the resulting solid, fig. 12, will still be a regular rhomboid; but the measures of its angles will be different from those of the former, and will be more

or less obtuse according to the degree of oblateness of the primitive spheroid.

It is at least possible that carbonate of lime and other substances, of which the forms are derived from regular rhomboids as their primitive form, may, in fact, consist of oblate spheroids as elementary particles.

It deserves to be remarked, that the conjecture to which we are thus led by a natural transition, from consideration of the most simple form of crystals, was long since entertained by HUYGHENS,* when treating of the oblique refraction of Iceland spar, which he so skilfully analysed. The peculiar law observable in the refraction of light by that crystal, he found might be explained on the supposition of spheroidical undulations propagated through the substance of the spar, and these he thought might perhaps be owing to a spheroidical form of its particles, to which the disposition to split into the rhomboidal form might also be ascribed.

By some oversight, however, the proportion of the axes of such an elementary spheroid is erroneously stated to be 1 to 8; but this is probably an error of the press, instead of 1 to 9,8, for I find the proportion to be nearly 1 to 9,87. In fig. 15, F is the apex of a tetrahedron cut from an acute rhomboid similar to fluor spar, and the sections of two spheres are represented round the centres F and C. I is the apex of a corresponding portion cut from the summit of a rhomboid of Iceland spar, as composed of spheroids having the same diameter as the spheres. In the former, the inclination FCT of the edge of the tetrahedron to its base is 54° 44′; in the latter, the inclination ICT is 36° 15′; and the altitudes FT, IT are as

* HUYGHENII Op. Reliq. Tom. I. Tract. de Lumine, p. 70.

the tangents of these angles 1414 to 499 :: 2,87 : 1, which also expresses the ratio of the axis of the sphere to that of the spheroid, or the proportional diameters of the generating ellipse.

Hexagonal Prisms.

If our elementary spheroid be on the contrary oblong, instead of oblate, it is evident that by mutual attraction, their centres will approach nearest to each other when their axes are parallel, and their shortest diameters in the same plane (fig. 13.) The manifest consequence of this structure would be, that a solid so formed would be liable to split into plates at right angles to the axes, and the plates would divide into prisms of three or six sides with all their angles equal, as occurs in phosphate of lime, beryl, &c.

It may further be observed, that the proportion of the height to the base of such a prism must depend on the ratio between the axes of the elementary spheroid.

The Cube.

Although I could not expect that the sole supposition of spherical or spheroidical particles would explain the origin of all the forms observable among the more complicated crystals, still the hypothesis would have appeared defective, if it did not include some view of the mode in which so simple a form as the cube may originate.

A cube may evidently be put together of spherical particles arranged four and four above each other, but we have already seen that this is not the form which simple spheres are naturally disposed to assume, and consequently this hypothesis

alone is not adequate to its explanation, as Dr. HOOKE had conceived.

Another obvious supposition is that the cube might be considered as a right angled rhomboid, resulting from the union of eight spheroids having a certain degree of oblateness (2 to 1) from which a rectangular form might be derived. But the cube so formed would not have the properties of the crystallographical cube. It is obvious, that, though all its diagonals would thus be equal, yet one axis parallel to that of the elementary spheroid would probably have properties different from the rest. The modifications of its crystalline form would probably not be alike in all directions as in the usual modifications of the cube, but would be liable to elongation in the direction of its original axis. And if such a crystal were electric, it would have but one pair of poles instead of having four pair, as in the crystals of boracite.

There is, however, an hypothesis which at least has simplicity to recommend it, and if it be not a just representation of the fact, it must be allowed to bear a happy resemblance to truth.

Let a mass of matter be supposed to consist of spherical particles all of the same size, but of two different kinds in equal numbers, represented by black and white balls; and let it be required that in their perfect intermixture every black ball shall be equally distant from all surrounding white balls, and that all adjacent balls of the same denomination shall also be equidistant from each other. I say then, that these conditions will be fulfilled, if the arrangement be cubical, and that the particles will be in equilibrio. Fig. 14 represents a cube so constituted of balls, alternately black and

white throughout. The four black balls are all in view. The distances of their centres being every way a superficial diagonal of the cube, they are equidistant, and their configuration represents a regular tetrahedron; and the same is the relative situation of the four white balls. The distances of dissimilar adjacent balls are likewise evidently equal; so that the conditions of their union are complete, as far as appears in the small group: and this is a correct representative of the entire mass, that would be composed of equal and similar cubes.

Since the crystalline form and electric qualities of boracite are perhaps unique, any explanation of properties so peculiar can hardly be expected. It may, however, be remarked, that a possible origin of its four pair of poles may be traced in the structure here represented; for it will be seen that a white ball and a black one are regularly opposed to each other at the extremities of each axis of the cube.

An hypothesis of uniform intermixture of particle with particle, accords so well with the most recent views of binary combination in chemistry, that there can be no necessity, on the present occasion, to enter into any defence of that doctrine, as applied to this subject. And though the existence of ultimate physical atoms absolutely indivisible may require demonstration, their existence is by no means necessary to any hypothesis here advanced, which requires merely mathematical points endued with powers of attraction and repulsion equally on all sides, so that their extent is *virtually* spherical, for from the union of such particles the same solids will result as from the combination of spheres impenetrably hard.

There remains one observation with regard to the spherical form of elementary particles, whether actual or virtual, that

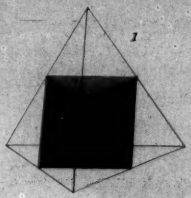
must be regarded as favourable to the foregoing hypothesis, namely, that many of those substances, which we have most reason to think simple bodies, as among the class of metals, exhibit this further evidence of their simple nature, that they crystallize in the octohedral form, as they would do if their particles were spherical.

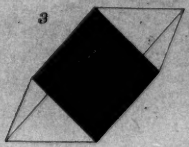
But it must, on the contrary, be acknowledged, that we can at present assign no reason why the same appearance of simplicity should take place in fluor spar, which is presumed to contain at least two elements; and it is evident that any attempts to trace a general correspondence between the crystallographical and supposed chemical elements of bodies must, in the present state of these sciences, be premature.

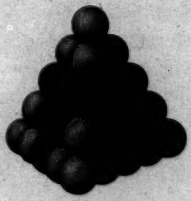
Note. A theory has lately been advanced * by M. FRANKENHEIM, which attempts to account for various crystalline forms from the different degrees of compression that soft spheres may be supposed to undergo in assuming the solid state. It is supposed, that with a certain degree of softness and of relative attraction, the particles will be surrounded each by four others, and will all be tetrahedral, although in fact it be demonstrably impossible that tetrahedrons alone should fill any space.

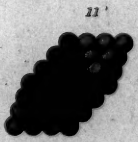
It is next supposed, that soft spheres less compressed will be surrounded by five others, and will be formed into triangular prisms, comprised under five similar and equal planes. That they should be similar is impossible, and it is further demonstrable, that when the triangular termination of such a

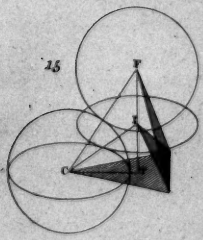
* Journal des Mines, No. 166.











Engraved by W. Lowry.

prism is equal in area to each rectangular side of the prism, so as to present equal resistance, according to the hypothesis, then the triangular faces will be nearer to the centre in the proportion of three to four, so that the attractions will not be equal as the hypothesis would require.

A third hypothesis of M. PRECHTL is, that the degree of compressibility may be such that each particle will be surrounded by six others, giving it the form of a cube, which, it must be admitted, is a very possible supposition.

All further application of the same hypothesis is precluded by M. PRECHTL, by denying that one particle can be surrounded by more than six others; although in fact it is most evident, that any sphere when not compressed will be surrounded by twice that number, and consequently by a slight degree of compression will be converted into a dodecahedron, according to the most probable hypothesis of simple compression.

VI. *On a Substance from the Elm Tree, called Ulmin.* By James Smithson, *Esq. F. R. S.*

Read December 10, 1812.

1. THE substance now denominated Ulmin was first made known by the celebrated Mr. KLAPROTH, to whom nearly every department of chemistry is under numerous and great obligations.*

Ulmin has been ranked by Dr. THOMSON, in his System of Chemistry, as a distinct vegetable principle, on the ground of its possessing qualities totally peculiar and extraordinary. It is said, that though in its original state easily soluble in water and wholly insoluble in alcohol and ether, it changes, when nitric, or oxymuriatic acid is poured into its solution, into a resinous substance no longer soluble in water, but soluble in alcohol, and this singular alteration is attributed to the union to it of a small portion of oxygen which it has acquired from these acids.* Being possessed of some of this substance which had been sent to me some years ago from Palermo, by the same person from whom Mr. KLAPROTH had received it, I became induced, by the foregoing account, to pay attention to it, and have observed facts which appear to warrant a different etiology of its phenomena, and opinion of its nature, from what has been given of them.

The ulmin made use of in the following experiments, had

* Dr. THOMSON's Syst. of Chem. Vol. IV. p. 696. Fourth edition.

been freed from the fragments of bark by solution in water and filtration, and recovered in a dry state by the evaporation of the solution on a water bath.

2. In lumps, ulmin appears black, but in thin pieces it is seen to be transparent, and of a deep red colour.

In a dilute state, solution of ulmin is yellow; in a concentrated one, dark red, and not unlike blood.

When solution of ulmin dries, either spontaneously or by being heated, the ulmin divides into long narrow strips disposed in rays to the centre, which curl up and detach themselves from the vessel, and the fluid part seems to draw together, and becomes remarkably protuberant. Solution of ulmin slowly and feebly restores the colour of turnsol paper reddened by an acid.

3. Dilute nitric acid being poured into a solution of ulmin, a copious precipitate immediately formed. The mixture was thrown on a filter. The matter which has been considered as a resin remained on the paper, and a clear yellow liquor came through. This yellow solution, on evaporation, produced a number of prismatic crystals looking like nitrate of potash. They were tinged yellow by some of the resin. This mixture, heated in a gold dish, deflagrated with violence, and a large quantity of fixed alkali remained.

Dilute muriatic acid caused an exactly similar precipitation in solution of ulmin to nitric acid, and the precipitate was the same resin-like substance. The filtered liquor afforded a quantity of saline matter, which, after being freed by ignition from a portion of dissolved resin, shot into pure white cubes of muriate of potash, as appeared by decomposing them by nitric acid.

Sulphuric, phosphoric, oxalic, tartaric, and citric acids, occasioned a similar precipitation in solution of ulmin.

Distilled vinegar produced no turbidness in it; and the mixture being exhaled to dryness, at a gentle heat, was found to be again wholly soluble in water. But when the mixture was made to boil, some decomposition took place. On adding muriatic acid to a mixture of solution of ulmin and distilled vinegar, a precipitate was produced, as in a mere solution in water.

The nitric and muriatic acids received a small quantity of lime and iron from the ulmin, and I believe also a little magnesia; but these can be considered only as foreign admixtures.

4. To acquire an idea of the quantity of potash in ulmin, 4 grains of ulmin were decomposed by nitric acid. They afforded 2.4 grains of resin-like matter. The nitrate of potash obtained was heated to deflagration, in small quantities at a time, in a platina crucible to free it from resin. The alkali produced was supersaturated with nitric acid, dried, and slightly fused. It then weighed 1.2 grains. If we admit $\frac{1}{2}$ of nitrate of potash to be alkali, this will denote $\frac{15}{100}$ of potash in ulmin.

5 grains of ulmin were decomposed by muriatic acid. The resinous matter weighed 3.3 grains, and the muriate of potash, after being ignited, dissolved away from the charcoal, dried, and again made red hot, weighed 1.4 grains. If we suppose $\frac{2}{3}$ of muriate of potash to be alkali, this will indicate $\frac{19}{100}$ of potash in ulmin.

2 grains of ulmin were made red hot in a gold crucible. It then weighed only 1.05 grain. The form of the flakes was

in no degree altered, but they had acquired the blue and yellow colours of heated steel, of which they had likewise the metallic aspect and lustre, and could difficultly, if at all, have been distinguished by the eye from heated steel-filings, or fragments of slender watch-springs. Water immediately destroyed their metallic appearance.

Muriatic acid, poured on, caused a strong effervescence, and formed muriate of potash, which, freed from all charcoal, and made red hot, weighed 0.6 grain, corresponding to $\frac{30}{100}$ of potash in ulmin.

These experiments assign about $\frac{1}{3}$ for the quantity of potash in ulmin, but as it is impossible to operate, on so small a scale, on such substances without loss, it is probable that it even exceeds this proportion.

5. The substance separated from ulmin by acids has the following qualities:

It is very glossy, and has a resinous appearance.

In lumps it appears black, but in minute fragments it is found to be transparent, and of a garnet-red colour.

It burns with flame, and is reduced to white ashes.

Alcohol dissolves it, but only in very small quantity.

Water likewise dissolves it, but also only in very small quantity. Acids cause a precipitate in this solution, though this resin-like matter appears neither to contain any alkali, nor to retain any of the acid by means of which it was obtained.

Its solution in water seems to redden turnsol paper.

Neither ammonia, nor carbonate of soda, promote its solution in cold water.

On adding a small quantity of potash to water in which it

lies, it dissolves immediately and abundantly. This solution has all the qualities of a solution of ulmin, and, on exhalation, leaves a matter precisely like it, which cracks and separates from the glass, and does not grow moist in the air, &c.

Hence it appears that ulmin is not a simple vegetable principle of anomalous qualities, but a combination with potash of a red, or more properly a high yellow matter, which, if not of a peculiar genus, seems rather more related to the extractives than to the resins.

English Ulmin.

I collected, from an elm tree in Kensington gardens, a small quantity of a black shining substance which looked like ulmin.

It was readily soluble in water, and the solution was in colour and appearance exactly similar to a solution of ulmin.

This solution, exhaled to a dry state on a water-bath, left a matter exactly like ulmin, and which cracked and divided as ulmin does, when dried in the same manner. It did not, however, rise up from the watch-glass in long strips, like the Sicilian kind, but this may have been owing partly to its small quantity, which occasioned it to be spread very thin on the watch-glass, and partly to its containing a considerable excess of alkali, for it differed also from the Palermo ulmin by becoming soft in the air, and its solution strongly restored the blue colour of reddened turnsol paper.

Nitric acid, added to a filtered solution of this ulmin, immediately caused a precipitate in it, and the filtered solution, on evaporation, afforded numerous crystals of nitrate of potash.

This English ulmin made a considerable effervescence with acetous acid, which the Palermo ulmin had not been observed to do. This acetous solution, in which the acid was in excess, was exhaled dry, and repeatedly washed with spirit of wine. No part of the brown matter dissolved. Water dissolved this brown residuum readily and entirely. This solution did not sensibly restore the blue colour of reddened turnsol paper. Exhaled to a dry state, the matter left did not separate from the watch-glass quite as freely as Palermo ulmin, which had been treated with acetous acid; but it seemed no longer to grow moist in the air. Redissolved in water, and nitric acid added, the mixture became thick from a copious precipitate.

The spirit of wine contained a quantity of acetate of potash.

The excess of alkali, in this English ulmin, may be owing to the tree from which it was collected having been affected with the disease, which produces the alkaline ulcer to which the elm is subject.

Sap of the Elm Tree.

Thinking that the production of ulmin by the plant might not be the consequence of disease, and that it might exist in the healthy sap, a bit of elm twig, gathered in the beginning of last July, was cut into thin slices and boiled in water. It afforded a brown solution, like a solution of ulmin. Exhaled to dryness, this solution left a dark brown substance, in appearance similar to ulmin, but on adding water to this dry mass, a large quantity of brown glutinous matter remained insoluble. The mixture being thrown on a filter, a clear yellow liquor passed, which may have contained ulmin, but the quantity was too small to admit of satisfactory conclusions.

Perhaps older wood, the juice of which was more perfected, would afford other results, since ulmin appears to be the product of old trees; but the inquiry, being merely collateral to the object I had originally in view, was not persevered in.

VII. *On a Method of Freezing at a distance.* By William Hyde Wollaston, *M. D. Sec. R. S.*

Read December 17, 1812.

THAT a fluid, from which a portion is evaporated, becomes colder in consequence of the heat absorbed by that part which assumes the gaseous state: that fluids rise in the state of vapour at a lower temperature when the pressure of the atmosphere is removed, and consequently may be cooled to a lower degree by evaporation *in vacuo* than in the open air, are facts too well known to need confirmation before the Members of this Society by any new experiments.

Nevertheless, a new mode of applying the most established principles may deserve to be recorded, if it assist the illustration of them, and be instructive from the novelty of the view in which it exhibits a certain class of phenomena; although no immediate use be at present proposed, to which it can be applied with advantage.

If an attempt were made to freeze water by evaporation, without other means than the vacuum of an air-pump, the pump must be of the best construction, and though the quantity of water be small, the receiver must be of large dimensions, otherwise its capacity would set too confined a limit to the quantity of vapour that will rise, and consequently to the degree of cold produced.

Supposing the commonly received estimates to be correct,

as to the quantities of heat, that become latent in the conversion of ice into water, and of water into steam, being 140° and 960° respectively, we should find the following statement to be not far from the truth.

If 32 grains of water were taken at the temperature of 62°, and if one grain of this were converted into vapour by absorbing 960°, then the whole quantity would lose $\frac{960°}{32} = 30°$, and thus be reduced to the temperature of 32°.

If from the 31 grains, which still remain in the state of water, 4 grains more were converted into vapour by absorbing 960°; then the remaining 27 grains must have lost $\frac{4}{27}$ of $960° = 142°$, which is rather more than sufficient to convert the whole into ice. In an experiment, conducted upon a small scale, the porportional quantity evaporated did not much differ from this estimate.

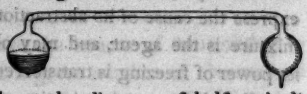
If it be also true, that water in assuming the gaseous state, even at a low temperature, expands to 1800 times its former bulk; then in attempting to freeze the small quantity of water abovementioned, it would be requisite to have a dry vacuum with the capacity of 5×1800, or equal to that of 9000 grains of water.

As a means of avoiding the necessity of so large a vacuum, Mr. LESLIE had recourse to the ingenious expedient of employing an extensive surface of sulphuric acid, for the purpose of absorbing the vapour generated in the course of the experiment, and by that means contrived to freeze much larger quantities of water, than could otherwise have been done, and by a far less laborious process.

But even in this method the labour is not inconsiderable,

and the apparatus, though admirably adapted to the purpose for which it is designed, is large and costly. I have therefore thought the little instrument I am about to describe may possess some interest, as affording a readier and more simple mode of exhibiting so amusing and instructive an experiment.

Let a glass tube be taken, having its internal diameter about $\frac{1}{4}$ of an inch, with a ball at each extremity of about one inch diameter; and let the



tube be bent to a right angle at the distance of half an inch from each ball. One of these balls should contain a little* water, and the remaining cavity should be as perfect a vacuum as can readily be obtained. The mode of effecting this is well known to those who are accustomed to blow glass. One of the balls is made to terminate in a capillary tube, and when water admitted into the other has been boiled over a lamp for a considerable time, till all the air is expelled, the capillary extremity, through which the steam is still issuing with violence, is held in the flame of the lamp till the force of the vapour is so far reduced, that the heat of the flame has power to seal it hermetically.

When an instrument of this description has been successfully exhausted, if the ball that is empty be immersed in a freezing mixture of salt and snow, the water in the other ball, though at the distance of two or three feet, will be frozen solid in the course of a very few minutes. The vapour contained in the empty ball is condensed by the common opera-

* If the ball be more than half full, it will be liable to burst by the expansion of water in freezing.

tion of cold, and the vacuum produced by this condensation gives opportunity for a fresh quantity to arise from the opposite ball, with proportional reduction of its temperature.

According to a theory that does not admit of positive cold, we should represent the heat of the warmer ball to be the agent in this experiment, generating steam as long as there remains any excess of heat to be conveyed. But if we would express the cause of its abstraction, we must say that the cold mixture is the agent, and may observe, in this instance, that its power of freezing is transferred to a distance, by what may be called the negative operation of steam.

The instrument, by which this is effected, may aptly be called a Cryophorus, which correctly expresses its office of frost-bearer.

VIII. *A Catalogue of North Polar Distances of some of the principal fixed Stars.* *By* John Pond, *Esq. Astronomer Royal, F. R. S.*

Read December 17, 1819.

THE catalogue which I have the honour of transmitting to the Society, is the result of a great number of observations made with the new Mural Circle, from the month of June last to the present time.

I hope at no very distant period to add considerably to its precision; but I trust that in its present state, it will not be thought unacceptable to astronomers, as from the experience I have now obtained of the instrument, I may safely pronounce that it far exceeds in accuracy any thing yet known in the history of practical astronomy.

In the fourth column I have annexed the degree of uncertainty, or maximum of error, to which I conceive the results are liable. These numbers not being derived from any strict mathematical process, must only be considered as indicating the opinion I have formed on the subject. When the observations themselves are laid before the Society, I shall have an opportunity of stating at length on what grounds this opinion was formed.

	Names of Stars.	N. P. Distances begin. 1813.	No. of Observations.	Maximum of Error to which this Catalogue may probably be liable.
		° ′ ″		
1	Polaris {Summer / Winter	1 41 22,07 / 1 41 21,47	120	
2	β Ursæ Min.	15 4 48,95	50	0,50
3	β Cephei	20 5 30,30	20	0,50
4	α Ursæ Maj.	27 14 31,50	36	0,50
5	α Cephei	28 12 12,35	20	0,50
6	α Cassiop.	34 29 22,83	38	0,50
7	γ Ursæ Maj.	35 15 55,10	10	0,75
8	γ Draconis	38 29 3,73	68	0,25
9	η Ursæ Maj.	39 44 57,80	50	0,25
10	α Persei	40 48 52,37	26	0,50
11	Capella	44 12 20,96	37	0,50
12	α Cygni	45 28 57,19	40	0,50
13	α Lyræ	51 23 0,72	70	0,25
14	Castor	57 42 46,57	30	0,50
15	Pollux	61 31 56,57	31	0,50
16	β Tauri	61 33 43,51	23	0,50
17	α Andromedæ	61 56 29,61	35	0,50
18	α Cor. Bor.	62 38 55,70	53	0,50
19	α Arietis	67 25 36,76	44	
20	Arcturus	69 50 19,04	50	0,25
21	Aldebaran	73 52 35,18	30	0,50
22	β Leonis	74 22 57,24	24	0,50
23	α Herculis	75 23 13,97	23	0,50
24	α Pegasi	75 47 51,77	20	0,50
25	γ Pegasi	75 51 21,00	25	0,50
26	Regulus	77 7 22,94	30	0,50
27	α Ophiuchi	77 17 39,66	37	
28	γ Aquilæ	79 50 0,62	38	0,75
29	α Aquilæ	81 36 58,88	45	
30	β Aquilæ	84 3 4,09	12	1,0 ‡
31	α Orionis	82 38 16,11	21	0,50
32	α Serpentis	82 58 39,50	33	0,50
33	Procyon	84 18 15,03	20	0,50
34	α Ceti	86 39 0,75	18	1,0 ‡
35	α Aquarii	91 13 21,64	20	0,50
36	α Hydræ	97 51 11,30	10	0,75
37	Rigel	98 25 33,85	30	1,0 ‡
38	Spica Virginis	100 10 51,30	20	1,0
39	1 α Capricor.	103 4 35,45	35	
40	2 α Capricor.	103 6 52,32	28	
41	1 α Libræ	105 12 39,26	10	
42	2 α Libræ	105 15 22,69	15	
43	Sirius	106 28 0,70	34	
44	Antares	116 0 16,63	36	

Total No. of Observations 1452.

* α Aquilæ, α Arietis, and α Ophiuchi are probably determined within a second of the truth, but I have met with some discordances in these stars which I do not comprehend; future observations will shew, whether these are accidental or arise from some periodical cause.

‡ Those stars marked ‡ were determined by the quadrant, its error having been determined by comparison with the circle, by other stars having nearly the same declination.

IX. *A Description of the solvent Glands and Gizzards of the Ardea Argala, the Casuarius Emu, and the long-legged Cassowary from New South Wales.* By Sir Everard Home, *Bart. F. R. S.*

Read December 17, 1812.

Having, upon a former occasion, laid before the Society an account of several varieties in the structure of the solvent glands and gizzards of birds, I now avail myself of some further materials, which I have procured since that time, to render the series more complete. The Ardea Argala, a native of Bengal, which feeds upon carrion, and is exceedingly voracious, has the solvent glands differently formed from those of any bird which I have examined; each gland is made up of five or six cells, and these open into one common excretory duct. The glands are disposed in two circular masses, one on the anterior, the other on the posterior surface of the cardiac cavity, putting on a similar appearance to those of the cormorant, but differing both in structure and situation. The gizzard of the Ardea Argala is lined with a horny cuticle, nearly of the same general appearance as that of the crow, and the digastric muscle is of similar strength. These parts are represented in the annexed drawing. (See Plate III.) This bird has a large bag hanging down on the forepart of the neck, which is rendered conspicuous by the skin that covers it being almost entirely without feathers, having only a few scattered on the most prominent depending part. The bag appears to

be readily filled and emptied at the will of the bird: upon examination after death, this bag was found to contain air, and to be unconnected with the organs of digestion, or the trachea which passes down along the middle of its cavity; it communicates by a large oval aperture with the air cells on the posterior part of the neck, and through them receives air from the lungs. The two species of casowary, Casuarius Emu, and the long-legged casowary from New South Wales, differ from one another in the form of their digestive organs, as well as in the length of their intestines.

In the Casuarius Emu, the solvent glands are oval bags one fourth of an inch long and only one sixteenth of an inch wide; they occupy the whole surface of the cardiac cavity which is very large, and they are all placed nearly in a transverse direction respecting the cavity, the orifices of the excretory duct appearing very distinctly through the membrane which lines the cardiac cavity. The gizzard is nearly of the strength of that of the crow, but has a thicker cuticular lining. This cuticle extends beyond the cavity of the gizzard both above its orifice and downwards towards the duodenum. The most remarkable circumstance respecting the gizzard, is its being situated out of the direction of the cardiac cavity, forming a pouch on the posterior part, and having before it an open channel lined with cuticle, along which the food can readily pass into the duodenum without being received into the gizzard, as in other birds. At the commencement of the duodenum there is a broad valve, upon the edge of which the cuticular lining of the cavity of the gizzard terminates. The duodenum, at its origin, swells out into an oval cavity four inches long, and two and an half in diameter; it then contracts to one inch and a half in dia-

meter, and the intestine afterwards continues nearly of that size.

In the long-legged casowary from New South Wales, the solvent glands are of the same length as those of the Emu, but are twice the width; they occupy the whole surface of the cardiac cavity, in the middle line of which there is a row of these glands in the direction of the cavity, and on the two sides the glands are arranged in an oblique direction towards this line. The gizzard is rather stronger than in the Emu, but resembles it in all other respects. The duodenum at its origin is by no means so large.

The annexed drawings (See Plates IV. V.) shew all the parts in so distinct a manner, as to make a more particular description of them unnecessary; and I feel myself much indebted to the kindness of Mr. Howship, who, in the absence of Mr. Clift, took the trouble of making them. His knowledge of comparative anatomy has enabled him to execute them in a much more satisfactory manner than could have been done by any artist who was not at the same time an anatomist.

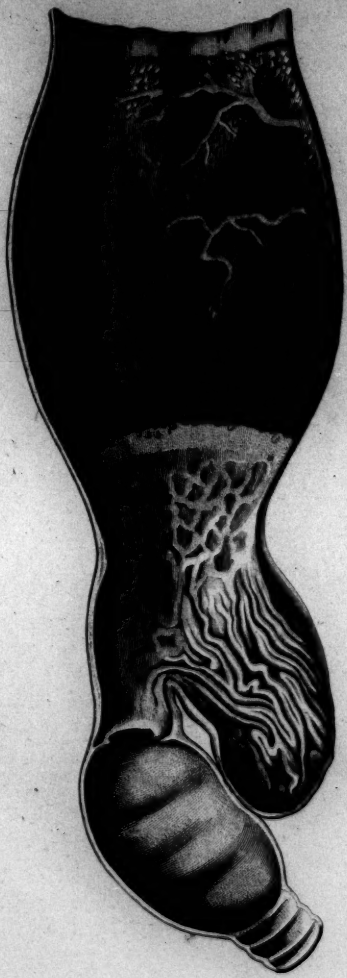
It is a very interesting part of comparative anatomy to examine the digestive organs belonging to birds, between which there is a similarity in size, food, and habits of life; and to trace the varieties in structure by means of which each species is enabled to subsist upon the produce of the country, of which it is the natural inhabitant, with every possible advantage. This cannot be better illustrated than by the following examples.

The Casuarius Emu, a native of Java, one of the most fertile and luxuriant islands in the world, has the solvent glands

of a very small size; the gizzard so situated as only to be used occasionally; the small intestines five feet long, two inches in diameter, and the great intestine one foot long, making in all six feet; and two cæca, each of them six inches in length, one-fourth of an inch in diameter. The Casowary of New South Wales, a less fertile country than Java, has larger solvent glands, a stronger gizzard placed under the same circumstances; the small intestines [illegible] and a quarter in diameter and ten feet seven inches long; the large, two inches in diameter, thirteen inches long, [illegible] feet; the cæca two inches long, and half an inch in diameter.

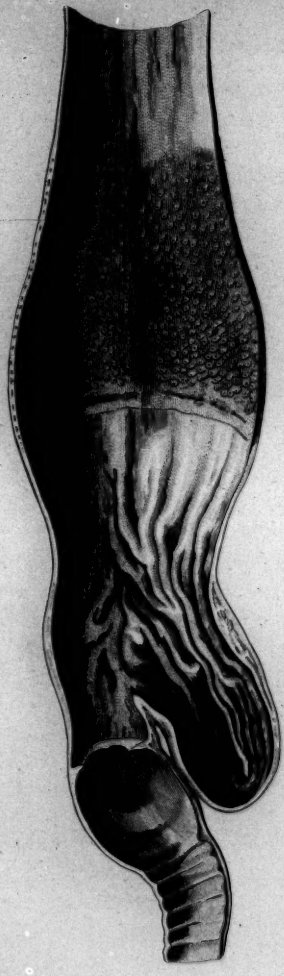
The Rhea Americana [illegible] America, where its food is not abundant, has solvent glands of an unusually complex form, and a strong gizzard, so placed that every part of the food must be triturated in it. The small intestines one inch in diameter, ten feet seven inches long; the large intestine one inch and a quarter in diameter, one foot eight inches long, in all twelve feet three inches; but to these are added two cæca, each of them three feet ten inches long, and two inches in diameter at the widest part.

The Struthio Camelus of [illegible] the Desert has a very precarious subsistence; [illegible] nds of the same structure as in the Rhea Ame[illegible] more numerous; a much stronger gizzard, [illegible] the food must undergo a previous trituration [illegible] ive at it; the small intestines one inch and [illegible] and twenty-seven feet long; the large [illegible] in diameter, and forty-five feet three inch[illegible] enty-two feet three inches; and [illegible] in diameter at the widest part, and each two [illegible] inches long.



J. Hourlip del.

J. Basire sc



J. Hawkins del.

E. Baxter sc.

In this series of structures, we have not only the gizzard becoming more and more fitted to economize the food as the country becomes less fertile, but we have also an extension of the lower intestines, and cæca, to such a degree as to lead to the belief that the processes carried on in them, render the undigested food subservient to the animal's support.

X. *Additional Remarks on the State in which Alcohol exists in fermented Liquors.* By William Thomas Brande, *Esq. F.R.S.*

Read December 17, 1812.

THE experiments and observations contained in this paper, are intended as supplementary to a communication on the same subject, which the Royal Society has done me the honour to insert in the Philosophical Transactions for the year 1811.*

On that occasion, I endeavoured to refute the commonly received opinion respecting the *production* of alcohol during the distillation of fermented liquors, by shewing, that the results of the process are not affected by a variation of temperature equal to twenty degrees of FAHRENHEIT's scale; that is, that a similar quantity of alcohol is afforded by distilling wine at 180° and at 200°.

I also conceived that any new arrangement of the ultimate elements of the wine, which could have given rise to the formation of alcohol, would have been attended with other symptoms of decomposition, that carbon would have been deposited, or carbonic acid evolved, which in the experiments alluded to, was not the case. Upon such grounds I ventured to conclude, that the relative quantity of alcohol in wines, might be estimated by submitting them to a careful distillation, and by ascertaining the specific gravity of the distilled liquor with the precautions which I have formerly described.

* Page 337.

This conclusion may be objected to, by supposing that the lowest temperature, at which the distillations were performed, was sufficient for the formation of alcohol from the elements existing in the wine; but it is not easy to conceive how this should happen, without some of those other changes which I have just noticed.

It has been stated, in my former paper, that the separation of alcohol from wine, by the addition of subcarbonate of potash, is prevented by the combination of the alkaline salt with the colouring-extractive, and acid contained in the liquor. I have also shortly noticed some unsuccessful attempts to separate these substances by other means than distillation.

In prosecuting the inquiry, this difficulty has been surmounted, and I shall proceed to shew, that alcohol may be separated from wine without the intervention of heat, and that the proportion thus afforded is equal to that yielded by distillation.

When the acetate,* or subacetate† of lead, or the subnitrate of tin‡ are added to wine, a dense insoluble precipitate is quickly formed, consisting of a combination of the metallic oxide, with the acid and colouring-extractive matter of the wine, and when this is separated by filtration, a colourless fluid is obtained, containing alcohol, water, and a portion of the acid of the metallic salt, provided the latter has not been added in excess, in which case a part remains undecomposed.

* Sugar of lead.

† Formed by boiling two parts of sugar of lead with one of finely powdered litharge, in six parts of water. The solution should be preserved in well closed phials, as it is rapidly decomposed by attracting carbonic acid from the atmosphere. Even while hot, a portion of carbonate of lead is formed in it.

‡ Prepared by dissolving protoxide of tin in cold dilute nitric acid.

The acetate of lead and the subnitrate of tin produce the desired effect of separating the colouring and acid matters, in the greater number of instances, but they are less rapid and perfect in their action, and not so generally applicable as the subacetate of lead,* which is the substance that I commonly employed.

The following experiment was made with a view to ascertain the effect of this salt.

Twenty measures of alcohol, specific gravity ,82500, were mixed with eighty measures of distilled water coloured with log wood, and rendered slightly acid by supertartrate of potash. Four measures of a concentrated solution of the subacetate of lead were added to this mixture, and the whole poured upon a filter. A precipitate was thus collected of a deep purple colour, which appeared to consist of oxide of lead combined with tartaric acid and the colouring-extractive matter.

The filtered liquor was perfectly transparent and colourless, and afforded, on the addition of subcarbonate of potash, 19,5 measures of alcohol.†

* The effect of this salt upon colouring matter, was first pointed out to me by Mr. E. M. NOBLE of Chelsea.

† Pure subcarbonate of potash, obtained by igniting the carbonate, was employed in these experiments. I found that about 19,5 parts of alcohol were separated in the course of four hours, by the addition of 50 parts of the subcarbonate to a mixture of 20 parts of alcohol by measure with 80 of distilled water, and that no further separation took place. The alcohol is always slightly alkaline, probably from containing a small portion of the solution of the subcarbonate, or of pure soda, but as this did not interfere with the object of the experiment, it was not particularly attended to.

When the subcarbonate was added to a mixture of four parts by measure of alcohol with 96 of water, no separation was effected.—A mixture containing 8 per cent. of alcohol afforded about 7 parts—one containing 16 per cent. about 15,5, and where the proportion of alcohol exceeded 16 per cent. the quantity, indicated by the action

Finding that the separation of alcohol by subcarbonate of potash from mixtures of spirit and water, was nearly complete, and that colouring-extractive matter, and tartaric acid might be removed from such mixtures by the subacetate of lead, I proceeded to examine wine by such modes of analysis.

The following results were obtained by these, and other comparative experiments.

1. One part by measure of a concentrated solution of subacetate of lead, was added to eight measures of common port wine: the mixture having been agitated for a few minutes, was poured upon a filter.—The filtrated liquor was perfectly colourless, and the addition of dry subcarbonate of potash effected a rapid separation of alcohol.*

100 measures of the wine thus treated, afforded 22,5 measures of alcohol.

2. Eight ounces of the wine employed in the last experiment, were distilled in glass vessels, as described in my former paper.—The specific gravity of the distilled liquor at the temperature of 60° was 0,97530, which indicates 22,80 per cent. by measure of alcohol of the specific gravity of ,8250.

3. Eight ounces of the same wine were introduced into a retort placed in a sand heat, and the process of distillation was stopped when six ounces had passed over into the receiver.

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of the subcarbonate, was always within 0,5 per cent. of the real proportion contained in the mixture. So that in the examination of wines containing less than 12 per cent. of alcohol, the method described in the text is somewhat exceptionable. The above experiments were made in glass tubes varying in diameter from 0,5 inch to 2 inches, and accurately graduated into 100 parts.

* When any excess of the subacetate had been employed, a portion of carbonate of lead was thrown down; but this did not interfere with the subsequent separation of the alcohol.

After the vessels were completely cooled, the portion in the receiver was added to the residuum in the retort. The specific gravity of this mixture (ascertained with proper precautions) was ,9884, that of the original wine = 0,9885.*

When care was taken to prevent the escape of vapour, no change of specific gravity was produced in the wine by three repetitions of the above process.

Similar experiments were repeated upon Madeira, Sherry, Claret, and Vin de grave, wines differing in the relative proportions of alcohol, colouring matter, and acid which they contain, and the results were as decisive; so that I conceive it is amply proved, by experimental evidence, that no alcohol is *formed* during the distillation of wines, and that the whole quantity found, after distillation, pre-existed in the fermented liquor.

It has been frequently asserted, that a mixture of alcohol and water, in the proportions I have stated them to exist in wine, would be much more effectual in producing intoxication, and the general bad effects of spirituous liquors, than a similar quantity of the wine itself. But this is true to a very limited extent only: when brandy is added to water, it is some time before the two liquids perfectly combine, and with alcohol this is more remarkably the case, and these mixtures are warmer to the taste, and more heating, if taken in this state of imperfect union, than when sufficient time has been allowed for their perfect mutual penetration.

I have also ascertained that distilled port wine tastes stronger, and is more heating than the wine in its original state, and that these qualities are impaired, and the wine reduced nearly

* This experiment was suggested in the Edinburgh Review for November, 1811.

to its original flavour, by the addition of its acid and extractive matter. With claret, and some other wines, containing less alcohol and more acid than port, these circumstances are more readily perceived; and lastly, if the residuum afforded by the distillation of 100 parts of port wine, be added to 22 parts of alcohol and 88 of water (in a state of perfect combination), the mixture is precisely analogous in its intoxicating effects to port wine of an equal strength.

In the table annexed to my former paper, it appears that the average quantity of alcohol contained in port wine amounts to 23,48 per cent.; but two of the wines there alluded to are stronger than any I have since met with, and were, at that time, sent to me as "remarkably strong and old port." I have lately examined a number of specimens of the better kinds of port wine in common use, and the results of these experiments lead me to place the average strength at 22 per cent. of alcohol by measure.

A port wine procured for me by Dr. BAILLIE, and to which no brandy had been added, afforded 21,40 per cent. of alcohol: another specimen of a similar description, put into my hands by an Oporto merchant, contained only 19 per cent.; it is the weakest port wine I have met with.

The other results given in the table, agree perfectly with those of subsequent and more extended experiments.

XI. *On a new Variety in the Breeds of Sheep. By Colonel* David Humphreys, *F. R. S. In a Letter to the Right Hon. Sir* Joseph Banks, *Bart. K. B. P. R. S.*

Read January 14, 1813.

SIR,

Humphreysville (in the State of Connecticut), Nov. 1, 1811.

I PROPOSE to give some account of a new variety in the breeds of sheep, which has lately sprung up in America.

SETH WIGHT, who possessed a small farm on the banks of Charles river, in the town of Dover and State of Massachusetts, about sixteen miles distant from Boston, kept a little flock composed of fifteen ewes and one ram. In the year 1791, one of the ewes produced a lamb of singular appearance. By the advice of some of his neighbours, he killed his former ram, and reserved the young one for breeding. The first season, two lambs only were yeaned in his likeness. In the following years, a number more, distinguished by the same peculiarities. Hence proceeded a strongly marked variety in this species of animals, before unknown in the world. It has been called by the name of the *Otter breed*.

This name was given from a real or imaginary resemblance to that animal, in the shortness of the legs and length of the back; by some supposed to have been caused by an unnatural intercourse; by others, perhaps as fancifully, from fright during gestation. It is only certain, that otters were then

sometimes seen on the banks of this river. They have since disappeared.

The person, who was the first to dissect one of these sheep for the purpose of ascertaining the properties and qualities which distinguish them from our common breed, has added the appropriate term of ANCON.

The singularity of form seems to be confirmed in the blood. Experiments, in crossing, have changed the strain, or, if I may be allowed so to express it, amalgamated the qualities of this with those of other breeds, so as to produce a mixed or mongrel race, in too few instances to form an exception to the theory.

When both parents are of the otter or ancon breed, the descendants inherit their peculiar appearance and proportions of form. I have heard of but one questionable case of a contrary nature.

The small number of cases where the young are said to partake in part, but not altogether, the characteristics of this breed, will not invalidate the general conclusions, established on experience in breeding from a male and female of distinct kinds.

When an ancon ewe is impregnated by a common ram, the increase resembles wholly either the ewe or the ram.

The increase of a common ewe, impregnated by an ancon ram, follows entirely the one or the other, without blending any of the distinguishing and essential peculiarities of both.

The most obvious difference between the young of this and other breeds, consists in the shortness of the legs of the former; which combined with debility or defect of organization, often makes them cripples in maturer age.

Frequent instances have happened where common ewes have had twins by ancon rams, when one exhibited the complete marks and features of the ewe; the other of the ram. The contrast has been rendered singularly striking when one short legged and one long legged lamb, produced at a birth, have been seen sucking the dam at the same time.

The facts respecting the fleeces have not been so well ascertained. They have been judged by some to be finer and heavier than those of our common breed; by others, of a medium fineness, but possessing more uniformity of pile on the same, and on different sheep of this kind. I have seen instances of their varying considerably from each other.

One case, where the young assumed the perfect likeness of the ewe, together with a meliorated pile apparently derived from the ram, is too interesting to be omitted. The inclosed specimen of wool, No. 1, is from an ancon-Merino: that is to say, the offspring of an ancon ewe and Merino ram. Its shape is the very image of the former: its wool, which covers almost the whole face, and extends quite down to the fetlocks, of a pretty fine quality (a common sign of the best blooded Merinos) partakes the silky feel and felting quality of the latter; with, I judge, about the same portion of fineness as the fleeces, which my quarter-blooded Merinos ordinarily carry. The locks, No. 2, 3, and 4, were clipped from a wether, ram and ewe descended immediately from ancon parents on both sides. The fleece of the former weighed four pounds and a half: those of the two latter somewhat rising three pounds each.

The ancons have been observed to keep together, separating themselves from the rest of the flock, when put into inclosures with other sheep.

The lambs are remarked to be less capable of standing up to suck without assistance, when first yeaned, than others.

Although they arrive somewhat later at maturity, the sheep are said to live as long as those of our common breeds; unless in some cases, where by reason of their debility and decrepitude, their health is impaired and their lives shortened.

To whatever cause it may be attributed, whether arising from defect in vertebræ, muscle, joint, or limb, it is certain that they can neither run nor jump like other sheep. They are more infirm in their organic construction, as well as more awkward in their gait, having their fore-legs always crooked, and their feet turned inwards when they walk. According to some information, the rams are commonly more deformed than the ewes.

Sprung from an individual, remarkable for what might be called a caprice of nature,* it is not one of the least extraordinary circumstances, that this misshapen and feeble race should propagate their own deformity and decrepitude until these characteristics have become constitutional and hereditary.

It may be asked with reason, why such a breed should have been continued?

The expectation of advantage, particularly in one way, doubtless prevailed over slighter considerations. We cannot boast of being such neat farmers, or of being so much attached to fine shapes in animals as the more skilful graziers and breeders in Europe; consequently the prospect of gain in some useful quality, or even of exemption from inconvenience, would more readily recompense us for the want of beauty, or reconcile us to the sight of what, to more acute or

* Lusus naturæ.

fastidious spectators, might be considered its opposite. The unfavourable appearance of Merinos, according to the generally received ideas of handsome proportions in sheep, is understood to have operated considerably in retarding their spread in France and England, as well as in a smaller degree in the United States of America.

The breed of ancons was expected to be a valuable acquisition, on account of their being less able than others to get over fences.

In New England, beyond which they have rarely migrated, there are few commons: no hedges: no shepherds: and no dogs, whose business it is to watch flocks. The small freehold estates are enclosed by fences of wood or stone. These are frequently too low to prevent active sheep from breaking out of pastures, into meadows, or grounds under cultivation. Crops are injured. Farmers discouraged. Hopes were entertained that this evil would be remedied. It has been in part.

To countervail this advantage, the drovers have complained of the great difficulty of driving these cripples to market; and the butchers, that the carcase is smaller and less saleable, than that of our common breeds. Perhaps, it is commonly not so fat. I have perceived little difference in the taste of the mutton; and presume, if served at table in equal condition, it would hardly be distinguished by better judges. They have been remarked not to fatten so easily, possibly owing to less facility or industry in gathering food, or to some fault in the organic system.

Since the introduction of Merinos, which are equally gregarious, quiet, and orderly, probably better feeders, and with greater disposition to take fat, and more highly recom-

mended by their fleeces, the ancon breed seems in danger of becoming almost extinct. They have so much declined, that, for many months, it was not an easy matter for me to procure one for dissection in Boston. That operation was performed by the ingenious Dr. SHATTUCK, who makes the following remarks.

"The sheep weighed just before it was killed forty-five "pounds. The most obvious difference in its skeleton from "the skeleton of the common sheep, so far as my superficial "observation has extended, consists in the greater looseness "of the articulations, the diminished size of the bones; but "more especially in the crookedness of its forelegs, which "causes them to appear like elbows, while the animal is walk-"ing. I have taken the liberty to call them *ancon*, from the "Greek word which signifies elbow. On dissecting the sheep, "I could not forbear noticing the comparatively flabby condi-"tion of the subscapularic muscles: this may partially account "for the great feebleness of the animal, and its consequent "quietude in pasture."

This skeleton will be presented to the President of the Royal Society, by the hand of the gentleman who is so obliging as to charge himself with the delivery of this letter.

I have been the more particular in the statement, because I deemed it important the point should be settled, so far as evidence can be adduced, that the preservation of different breeds, once clearly designated, in whatever manner obtained, whether from casualty, as in the present instance, or from calculation and cultivation, as in that of the new Leicester breed, depends more on some inherent quality in the blood, than on climate, food, or any other circumstance. Although it is allowed

that these have no inconsiderable influence, particularly the first, on the fleece, in the torrid zone. In all temperate regions, and even in the higher latitudes, where extreme cold prevails, flocks may be improved by care, or deteriorated by the want of it.

The settlement of this point would not fail to have a tendency to eradicate the remains of the pernicious prejudice, that the Merinos of Spain cannot be bred out of that country, without degenerating and losing their essential character for wool.

The beneficent Creator having ordained "that all creatures shall increase after their kinds," has still left much for man to do, in regard to those which are made more immediately subservient to his use.

We are not ignorant how much the agricultural nations of Europe and America are indebted for meliorations in their husbandry to modern researches and discoveries in chemistry, natural history, and other branches of philosophy; as well as to experiments of eminent farmers, and especially breeders of cattle.

My experience has been too limited for me to flatter myself with being able to add to the stock of materials for investigation and improvement, except by becoming in some degree the medium of communication between the agriculturalists of the two continents.

I have formerly exerted myself to enable my countrymen to improve their breeds of useful animals, perhaps not altogether without success. My present object should rather be, to supply facilities and inducements for abler men, possessed of better opportunities, to discover and disclose the best means

for selecting and spreading the most approved breed of fine woolled sheep, by which Merinos are meant, throughout the different countries which are known to be well adapted to their cultivation.

So tempting a motive for contributing my mite to the repertory of a Society, justly celebrated for the extension of human knowledge and improvements, and which has done me the honour to enrol my name in their number, was not to be resisted; and the less, as it affords me occasion of presenting, at the same time, the homage of high respect for their President, with which I have the honour to be,

Sir, your most obedient servant,

D. HUMPHREYS.

XII. *Experiments to ascertain the coagulating Power of the Secretion of the gastric Glands. By Sir* Everard Home, *Bart. F. R. S. Communicated by the Society for promoting the Knowledge of Animal Chemistry.*

Read January 21, 1813.

In attempts to investigate the process of digestion in quadrupeds, the difficulties are almost insurmountable; the gastric glands are scarcely perceptible, and occupy a small portion of the stomach, every other part of the inner membrane is throwing out secretions of a different kind, and these are all mixed together with the food in the general cavity. Under such circumstances, the properties of the secretion of the gastric glands can never be ascertained, since it cannot be procured in a pure state. It is generally allowed, that the first process the food undergoes in the stomachs of animals is being converted into a jelly; but whether this is produced by the gastric liquor as the previous change to dissolution, or whether it takes place before that liquor is applied, has not been ascertained.

Mr. Hunter made many experiments upon the coagulating power of the secretions of the stomach, which establish the fact of coagulation taking place in the stomachs of animals of different classes.

An infusion of the dried inner membrane of the fourth cavity of the stomach of the calf, being in common use for

the purpose of coagulating milk, proves, that every part of that membrane possesses such a power.

Mr. HUNTER ascertained, that the mucus found in the first, second, and third cavity of the calf's stomach, dissolved in water, had no power of coagulating milk, while a solution of the mucus of the fourth cavity possessed that property, and retained it even after it had been so long kept, as to begin to become putrid.

When the calf has left off sucking, and is old enough to be killed for veal, the inner membrane of the fourth cavity of the stomach readily coagulates milk.

If different portions of the inner membrane of the hog's stomach are prepared as rennet, no part coagulates milk but that near the pylorus, and I have shewn, in a former paper, that the gastric glands are situated there.

The crop and gizzard of a cock were prepared as rennet, milk was coagulated in half an hour by that of the gizzard, in two hours by that of the crop.

The contents of a shark's stomach coagulated milk immediately; portions of the stomach washed and steeped sixteen hours in water, formed a solution which produced the same effect.

Rennet made from the stomach of a salmon coagulated milk in four or five hours; when made from the stomach of the thornback, it produced the same effect.

These experiments shew, that the secretions of the stomach have a power of coagulating milk; they do not, however, explain whether this power belongs to any one secretion in particular, or to a mixture of them all.

With a view to ascertain to what particular secretions this

property belongs, I instituted the following experiments, which were made by my fellow labourers in animal chemistry, Mr. HATCHETT and Mr. W. BRANDE.

On the 9th of June, 1812, Mr. HATCHETT took the cardiac portion of a chicken's stomach with the gastric glands that open into it, and put it into a glass vessel; the horny lining of the gizzard was put into another, milk was added to each, and was converted into a curd; but the curd in the vessel containing the lining of the gizzard was the firmest.

Mr. BRANDE, on the 12th of June, 1812, made a similar experiment with the cardiac portion of the stomach of the hawk, as a carnivorous bird, in one vessel; and the cardiac portion of the fowl, as a granivorous one, in another. The coagulating power of the hawk's stomach was found to be the most powerful.

To ascertain whether the coagulating power belongs to the secretion of the gastric glands, and is only communicated to the other parts, I instituted the following experiment, which was made by Mr. BRANDE on the 13th of July, 1812. I selected the turkey for the subject of it, as the gastric glands of that bird are larger than in most others. The turkey had been kept one day without food before it was killed, and immediately after death the gastric glands were very carefully dissected from each other, on the outside of the membrane which lines the cardiac cavity without opening into it, each gland was then separately removed by cutting through the excretory duct, leaving the cardiac cavity entire and unopened.

Of these glands slit open 40 grains were put into a vessel, and two ounces of new milk added.

40 grains of rennet were put into a second vessel, to which the same quantity of milk was added.

40 grains of the lining of the cardiac cavity of the turkey, and the same quantity of milk were put into a third vessel.

40 grains of the fourth cavity of a calf's stomach in a recent state, with the same quantity of milk, were put into a fourth vessel.

The experiment commenced at ten o'clock in the morning, at half past ten the milk with the rennet became thick, at twelve curd was formed, at two whey separated, at four the formation of curds and whey appeared complete.

At half past eleven the milk with the glands became thick, at one curd was formed, at three whey separated, at six the formation of curds and whey was complete.

The milk with the portion of the recent calf's stomach underwent the same changes at the same periods.

The milk with the cardiac membrane of the turkey at four became thick, at eight curd was formed, the separation into curds and whey was not complete till next morning.

A portion of the same milk in twenty-four hours had undergone no change, except that cream had separated.

The rennet in a dried state consisted of four times the quantity of membrane employed in the experiment with the recent calf's stomach, which accounts for its more readily producing coagulation.

From these experiments, it is clear that the secretion of the gastric glands possesses the power of coagulating milk, and gives that power to all the parts by which it is imbibed, whether composed of living parts or not, since the horny lining

of the gizzard, the mucus in the stomach, and the inner membrane of that cavity appear equally to have acquired it.

This coagulation appears to be the first change the food undergoes in the process of digestion, and where the digestion is rapid, the coagulated parts are very quickly dissolved.

Mr. BULLOCK was led, by his love of natural history, to spend some time on the Bass Rocks, and has frequently seen a Solan goose swallow a herring, and come immediately to feed its young, and although the time the herring remained in its stomach could not have been more than a few minutes, when it was brought up again, to be given to the young bird, the external covering was entirely dissolved.

XIII. *On some Properties of Light.* By David Brewster, *LL.D. F.R.S. Edin.* *In a Letter to Sir* H. Davy, *LL.D. F.R.S.*

Read January 28, 1813.

Dear Sir,

Having been for some time engaged in a series of experiments on the phenomena of light arising from its transmission through diaphanous bodies, I have taken the liberty of communicating to you, for the information of the Royal Society, a short and general account of the results of my enquiries. In the narrow compass of a letter, it would be impracticable to include the various details of these experiments; the particular methods of observation that were employed; or the numerical results which I have obtained for the refractive and dispersive powers of nearly two hundred substances. As these will form part of a separate work, in which I am now engaged, I shall confine myself at present to some of those results which appear to be most interesting, either from their novelty or importance.

1. *On a new Property of refracted Light.*

As you are already well acquainted with the optical properties of doubly refracting media, and the analogous property of reflected light discovered by Malus, it will be unnecessary to take any notice of these phenomena. After repeating the experiments of Malus, and measuring several of the angles

of incidence at which this property was communicated to light by reflection from different substances, I made a variety of experiments, with the view of discovering if a similar character could be impressed upon light by its *transmission* through bodies, either wholly or imperfectly transparent. All these experiments afforded no new result, and every hope of discovering such a property was extinguished, when my attention was directed to a singular appearance of colour in a thin plate of agate. This plate, bounded by parallel faces, is about the fifteenth of an inch thick, and is cut in a plane perpendicular to the laminæ of which it is composed. The agate is very transparent, and gives a distinct image of any luminous object; but on each side of this image is one highly coloured, forming with it an angle of several degrees, and so deeply affected with colour that no prism of agate, with the largest refracting angle, could produce an equivalent dispersion. Upon examining this coloured image with a prism of Iceland spar, I was astonished to find that it had acquired the same property as if it had been transmitted through a doubly refracting crystal, and upon turning the Iceland spar about its axis, the images alternately vanished at every quarter of a revolution. My attention was now directed to the common colourless image formed by pencils transmitted perpendicularly through the agate; and by viewing it through a prism of Iceland spar, it exhibited all the characters of one of the pencils produced by double refraction, the images alternately vanishing in every quadrant of their circular motion.

When the image of a taper reflected from water at an angle of 52° 45′, so as to acquire the property discovered by MALUS, is viewed through the plate of agate, so as to have its laminæ

parallel to the plane of reflection, it appears perfectly distinct; but when the agate is turned round, so that its laminæ are perpendicular to the plane of reflection, the light which forms the image of the taper *suffers total reflection, and not one ray of it penetrates the agate.*

If a ray of light incident upon one plate of agate is received after transmission upon another plate of the same substance, having its laminæ parallel to those of the former, the light will find an easy passage through the second plate; but if the second plate has its laminæ perpendicular to those of the first, the light will be wholly reflected, and the luminous object will cease to be visible.

Owing probably to a cause which will afterwards be noticed, there is a faint nebulous light unconnected with the image, though always accompanying it, and lying in a direction parallel to the laminæ. This light never vanishes along with the images, though it is evidently affected by the different changes which they undergo; and in one of the specimens of agate, it is distinctly incurvated, having the same radius of curvature with the adjacent laminæ. This character of the nebulous light I consider as an important fact, which may be the means of conducting us to a satisfactory theory, and I am at present engaged in examining it with particular care.

This remarkable property of the agate I have found also in the kindred substances of cornelian and chalcedony, and it is exhibited in its full effect even when these bodies are formed into prisms, and when the incident rays fall with any angle of obliquity. In one specimen of agate, which has no veins to indicate the direction in which it was cut, the images did not vanish as before; and in another specimen of the same

character the images suffered only an alternate diminution of brightness, in the same manner as a pencil of light receives only a partial modification when reflected from water at a greater or a less angle than 52° 45′.

The different experiments which have now been mentioned were repeated, with the most satisfactory results, by Mr. PLAYFAIR, Dr. HOPE, and Mr. JOHN DAVY.

Although the preceding results are by no means ripe for generalization, I cannot omit the present opportunity of hazarding a few conjectures respecting the cause of this singular property of the agate.

May not the structure of this mineral be in a state of approach to that particular kind of crystallization which affords double images? and may not the nebulous light be an imperfect image arising from that imperfection of structure? When one of the images vanishes, the nebulous light which encircled it is then a maximum, and it gradually diminishes during the re-appearance of the image. When the image which had disappeared recovers its full lustre, the surrounding nebulosity is very small, and this remaining light is, in all probability, no portion of the unformed image, but merely a few scattered rays arising from the imperfect transparency of the mineral.

By forming the agate into a prism, the nebulous light should be separated from the image which it encloses, in proportion to the angle contained by the refracting planes; but owing, perhaps, to the smallness of its double refraction, if it has such a property, I have not observed any separation of this kind.

The incurvated form of the nebulous light corresponding with the curvature of the laminæ, seems to connect it with the

laminated structure of the agate, and to indicate that the phenomena of double refraction are produced by an alternation of laminæ of two separate refractive and dispersive powers. In Iceland spar, one set of the laminæ may be formed by a combination of oxygen and calcium, while the other set is formed by a combination of oxygen and carbon. In chromate of lead, the chromium and oxygen may give one image, while the oxygen and lead give another. In like manner the carbonate of lead, the carbonate of strontites, jargon, and other crystals may give double images, in virtue of similar binary combinations. Of the simple inflammable bodies, sulphur is the only one which has the property of double refraction, but it will probably be found that it holds a metal or some other ingredient in its composition, which chemists have not been able to discover.

If the explanation which has now been given of the polarising power of the agate should be confirmed by future experiments, this property will be considered as a case, though a very curious one, of double refraction; but if these conjectures should be overturned, the phenomena which we have described must be ranked among the most singular appearances in the wide range of optical science.

2. *On the double Refraction of Chromate of Lead.*

In the course of my experiments on refractive powers, I discovered a double refraction in this metallic salt of such enormous magnitude, that the deviation of the extraordinary ray is more than thrice as great as that produced by Iceland spar. The ratio of the sines, for both refractions, and the other

properties of this extraordinary mineral will be noticed in the next article.

3. *On Substances with a higher refractive Power than the Diamond.*

Since the time of Sir ISAAC NEWTON, who first measured the action of the diamond upon light, its refractive power has been regarded as superior to that of every other substance; but, in the course of my researches, I have found that realgar and chromate of lead exceed the diamond in refractive power, and that this high refraction, in both these substances, is accompanied with dispersive powers greater than those of any other body. The following are the measures which I have obtained for these, and a few other substances.

Refractive Powers.

	Index of Refr.		Index of Refr.
Chromate of lead (gr. refr.)	2.926	Phosphorus	2.224
Ditto, least refraction	2.479	Sulphur, native	2.115
Realgar	2.510	Cryolite	1.344
Diamond (according to NEWTON)	2.439	Ice	1.307

Dispersive powers or values of $\frac{dR}{R-1}$.

Chromate of lead (gr. refr.)	0.400	Phosphorus	0.128
Ditto, least refraction	0.262	Flint glass (highest)	0.052
Realgar	0.255	Diamond	0.038
Oil of cassia	0.189	Water	0.035
Sulphur	0.130	Fluor spar	0.022
		Cryolite	0.022

It appears from the first of these tables, that phosphorus

is next to diamond in refractive power, and that the three simple inflammable substances have their refractive powers in the order of their inflammability. Dr. WOLLASTON has placed phosphorus below horn and flint glass,* but I am confident that this distinguished philosopher, to whom the physical sciences are so deeply indebted, will find, upon making the experiment with prisms or lenses, that I have assigned the right place to that remarkable substance. The difference between the extreme dispersive powers in the second table is very remarkable, and the result for oil of cassia indicates in that body the existence of some ingredient, which chemical analysis has not been able to detect.

4. *On the Existence of two dispersive Powers in all doubly refracting Crystals.*

It has been long known, and it is indeed obvious, from a simple inspection of the images formed by a prism of Iceland crystal, that the one image is more coloured than the other, or that the actual *dispersion* of the one refraction is greater than the *dispersion* of the other, in the same manner as the *dispersion* of a prism of flint glass with a refracting angle of 12 degrees, is greater than the dispersion of a prism of the same glass with an angle of only 10 degrees.

Dr. WOLLASTON, who was the first person that examined the subject of dispersive powers with philosophical accuracy, makes the dispersive power of Iceland spar considerably above water, and even above diamond. Upon repeating this experiment, with the least refracted image, I found the dispersive

* Dr. WOLLASTON is satisfied that his original estimate was erroneous, and that Dr. BREWSTER's determination is very near the truth. H. D.

power, or the value of $\frac{dR}{R-1}$, to be 0.026 very considerably below water, which stands at 0.035 of the scale, and I therefore concluded that Dr. WOLLASTON had examined the greatest refraction, while I had examined the least, and that the vast discrepancy between our measures arose from the existence of a double dispersive power. This conclusion was confirmed by determining the dispersive power of the greatest refraction, which coincided exactly with the order assigned to it by Dr. WOLLASTON.

The dispersive powers, which I have obtained for other doubly refracting crystals, such as carbonate of strontites, carbonate of lead, and chromate of lead, have confirmed this result, and establish the general law, that each refraction of crystals which give double images is accompanied with a separate dispersive power. The double dispersive powers of these bodies are given in the following table.

Chromate of lead (gr. refr.) estimated at	0.400
Ditto Ditto must exceed	0.296
Ditto (least refr.) - -	0.262
Carbonate of lead (gr. refr.) -	+ 0.091
Ditto (least refr.) - -	0.066
Carbonate of strontites (gr. refr.) -	0.046
Ditto (least refr.) -	0.027
Calcareous spar (gr. refr.) - -	0.040
Ditto (least refr.) -	0.026

In a table of refractive powers, published by the late Mr. CAVALLO, he has given, from other authors, the *dispersions*, or the *dissipations* as he calls them, of a few substances, and he has annexed a different *dispersion* to the two refractions of

Iceland crystal; but it is obvious, from a simple inspection of the table, that these are measures of the *dispersion* or *quantity of colour*, and not of the *dispersive power* of the substances. The measures in the table alluded to, with the exception of one or two, are so completely incompatible with those taken by Dr. WOLLASTON and myself, that I can scarcely believe that the experiments were ever made.

The singular property of a double dispersive power, while it seems to exclude some of the theories by which the double refraction has been explained, adds another to those numerous difficulties with which philosophy has yet to struggle, before she can reduce to a satisfactory generalization those anomalous and capricious phenomena which light exhibits in its passage through transparent bodies.

I have the honour to be,

dear Sir,

your most obedient humble servant,

DAVID BREWSTER.

Edinburgh, 23, Duke-street,
December 19, 1812.

To Sir H. Davy, LL.D. F.R.S.

XIV. *An Appendix to Mr.* Ware's *Paper on Vision.* *By Sir* Charles Blagden, *F. R. S.*

Read February 4, 1813.

Mr. Ware states in his Paper, that near sightedness comes on most frequently at an early age; that it is more common in the higher than in the lower ranks of life; and that particularly at the universities, and various colleges, a large proportion of the students make use of concave glasses. All this is exactly true, and to be accounted for by one single circumstance; namely, the habit of looking at *near* objects. Children born with eyes which are capable of adjusting themselves to the most distant objects, gradually lose that power soon after they begin to read and write; those who are most addicted to study become near sighted more rapidly; and, if no means are used to counteract the habit, their eyes at length lose irrecoverably the faculty of being brought to the adjustment for parallel rays. Of this I am myself an example, and as I recollect distinctly the progress, it may not be useless to record it here.

When I first learned to read, at the usual age of four or five years, I could see most distinctly, across a wide church, the contents of a table on which the Lord's Prayer, and the Belief, were painted in suitably large letters. In a few years, that is, about the ninth or tenth of my age, being much addicted to books, I could no longer read what was painted on this table; but

the degree of near sightedness was then so small, that I found a watch-glass, though as a meniscus it made the rays diverge very little, sufficient to enable me to read the table as before. In a year or two more, the watch-glass would no longer serve my purpose; but being dissuaded from the use of a common concave glass, as likely to injure my sight, I suffered the inconvenience of a small degree of myopy, till I was more than thirty years of age. That inconvenience, however, gradually though slowly increasing all the time, at length became so grievous, that at two or three and thirty, I determined to try a concave glass; and then found, that the numbers 2 and 3 were to me in the relation so well described by Mr. WARE; that is, I could see distant objects tolerably well with the former number, but still more accurately with the latter. After contenting myself a little time with N°. 2, I laid it wholly aside for N°. 3; and, in the course of a few more years, came to N°. 5, at which point my eye has now been stationary between fifteen and twenty years. An earlier use of concave glasses would probably have made me more near sighted, or would have brought on my present degree of myopy at an earlier period of life. If my friends had persuaded me to read and write with the book or paper always as far from my eye as I could see; or if I had occasionally intermitted study, and taken to field sports, or any employment which would have obliged me to look much at distant objects, it is very probable that I might not have been near sighted at all. Possibly the persons who become near sighted by having constantly to adjust their eyes to near objects, may not usually change to be long sighted by age.

On the subject of vision, I may be allowed to take this

opportunity of relating an experiment made many years ago, to decide how far the *similarity* of the images seen by each eye contributed to make them impress the mind as *one*. In the house where I then lived was a marble chimney-piece, the upper horizontal block of which was fluted vertically; and the ridge between each concavity of the fluting was about as wide as the concavity itself. When I looked at this range of fluting at the distance of about nine inches, and directed the optic axes to it, I saw of course every ridge and concavity distinctly, and judged rightly of the distance. Adjusting the optic axes as to an object a little further off, I discerned the fluting confusedly and all double, the ridges interfering with the concavities; which was accompanied with the uneasy sensation of squinting. But on widening the direction of the optic axes still more, as to an object about eighteen inches distant; (namely, just so far that the duplication of the images should correspond successively; that is, so that the first ridge and concavity of the fluting, as seen by one eye, should fall in with the second ridge and concavity, as seen by the other;) the fluting appeared as distinct and as single as at first; but it seemed to be about double the distance from the eye that it really was, and to be magnified in proportion; nor had I, in this case, any sensation of squinting. As the parts of the fluting, though in general much alike, were not exactly so every where in colour and minute circumstances, there appeared in some places a slight confusion from this dissimilarity of the images; but that trifling confusion had no manner of effect on the mind's judgment of the images, which looked as perfectly single, as when the fluting was viewed with the optic axes so directed, that the ridges and concavities seen by

one eye corresponded with the same ridges and concavities as perceived by the other. No idea was suggested, but that of a range of fluting larger and more distant than it was in fact. This experiment I frequently repeated, and always with the same effects.

XV. *A Method of drawing extremely fine Wires.* By William Hyde Wollaston, *M. D. Sec. R. S.*

Read February 18, 1813.

It is recorded by Musschenbroek, that an artist of Augsburg drew a wire of gold so slender, that five hundred feet of it weighed only one grain; but the method by which this was effected is not mentioned, and indeed it has been doubted, whether it could really have been done. I shall however shew, that a wire of gold may, without much difficulty, be obtained finer than that spoken of by Musschenbroek, and that wires of platina may be drawn much more slender, with the utmost facility.

Those who draw silver wire in large quantities for lace and embroidery, sometimes begin with a rod that is about three inches in diameter, and ultimately obtain wires that are as small as $\frac{1}{100}$ of an inch in thickness. If in any stage of this process a rod of silver wire be taken, and a hole be drilled through it longitudinally, having its diameter one-tenth part of that of the rod, and if a wire of pure gold be inserted, so as to fill the hole, it is evident that by continuing to draw the rod, the gold within it will be reduced in diameter exactly in the same proportion as the silver; so that if both be thus drawn out together till the diameter of the silver is $\frac{1}{1000}$ of an inch, then that of the gold will be only $\frac{1}{10000}$; and of such wire five hundred and fifty feet would be requisite to weigh one grain.

For the purpose of removing the coating of silver that surrounds it, the wire must be steeped for a few minutes in warm nitrous acid, which dissolves the silver without danger of doing any injury to the gold. And though it might be difficult in this manner to preserve any considerable length of such wires, it is of little importance for any of those uses to which it is likely to be applied.

In my endeavours to make slender gold wires by the method above described, the difficulty of drilling the central hole in a metal so tough as fine silver, was greater than I had expected, and I was induced to try whether platina might not be substituted for the gold, as in that case its infusibility would allow me to coat it with silver without the necessity of drilling.

Having formed a cylindrical mould $\frac{1}{4}$ of an inch in diameter, I fixed in the centre of it a platina wire previously drawn to the $\frac{1}{100}$ of an inch, and then filled the mould with silver. When this rod was drawn to $\frac{1}{30}$, my platina was reduced to $\frac{1}{1000}$, and by successive reduction I obtained wires of $\frac{1}{4000}$ and $\frac{1}{5000}$, each excellent for applying to the eye-pieces of astronomical instruments, and perhaps as fine as can be useful for such purposes.*

Since this had been the primary object that I had in view, I should have thought my time ill bestowed in pursuing farther the practical application of a method to which there seems no limit, except the imperfections of the metal employed. But as I found by trial the tenacity of these wires to be greater than was to be expected in proportion to their substance, that

* No very accurate observations can be made with a telescope shorter than thirty inches, and at that distance $\frac{1}{2160}$ of an inch subtends only one second of a degree.

circumstance excited some doubts regarding the correctness of the estimate by which their diameter had been deduced. Other wires were consequently drawn with the utmost care, as to the quality and substance of the platina employed, and as to the proportional reduction of its diameter in the process of wire-drawing.

The extremity of a platina wire having been fused* into a globule nearly $\frac{1}{4}$ of an inch in diameter, was next hammered out into a square rod, and then drawn again into a wire $\frac{1}{253}$ of an inch in diameter. One inch of this wire duly coated with silver was drawn till its length was extended to 18$\frac{1}{2}$ inches, consequently the proportional diminution of the diameter of the platina will be expressed by the square root of 18$\frac{1}{2}$, so that its measure had become $\frac{1}{253 \times 13{,}5} = \frac{1}{3425}$. The specific gravity of the coated wire was assumed to be 10,5, and since the weight of 100 inches was 114 grains, its diameter was inferred to be $\frac{1}{4218}$ of an inch, or just eighty times that of the platina contained in it.

With portions of the platina wire thus obtained, and successively reduced in diameter, I had an opportunity of repeating the trials of its tenacity with greater confidence in the justness of the estimate, and the results shewed generally (though with some accidental exceptions) that the process of wire-drawing, which is well known to improve the strength of

* I am indebted to my friend Dr. Marcet for the simple and easy method by which the fusion was effected. A piece of wire, about six inches long, having been bent to an angle in the middle, one half of its length was held in the flame of a spirit lamp impelled by a current of oxygen, and its extremity was thus fused in about half a minute.

metals within moderate limits, continued also to add something to the tenacity of platina even as far as $\frac{1}{18,000}$ of an inch, which supported $1\frac{1}{4}$ grain before it broke; but the wire on which these experiments were made began then to be impaired by repetition of the operation: so that although I afterwards obtained portions of it, as small as $\frac{1}{30,000}$ of an inch in diameter, it was in many places interrupted, and I could place no reliance upon any trials of its tenacity.

There are some little circumstances in the management of these fine wires, which it may be of advantage to describe for the assistance of those who would apply them to any useful purpose. When the diameter is not less than $\frac{1}{1000}$ or $\frac{1}{1000}$ of an inch, the difficulty of seeing and applying them in short pieces is not considerable; but when their diameter is farther reduced, and their length as much as an inch or more, the slightest current of air is sufficient to defeat all attempts to lay hold of an object so difficult to see, and so impossible to feel. It is therefore necessary to retain a part of the silver coating at each extremity, which, at the same time that it assists in finding the end, also serves to stretch the wire with a certain moderate tension, and affords the means of attaching it in any required position.

The method that I have found most convenient is to bend a portion of the coated wire into the shape of the letter U, with small hooks at its upper extremities. In this form it will conveniently hang upon a wire of gold or of platina, with the lowest part immersed in nitrous acid, till the coating of silver is removed from that part. It may then, without difficulty, be

lifted from its place, by one of the hooks alone, to any other situation, or suspended by it, with the other hook downwards, as the means of attaching a small chain, or other series of equal weights in trials of its tenacity.

XVI. *Description of a single-lens Micrometer.* *By* William Hyde Wollaston, *M. D. Sec. R. S.*

Read February 25, 1813.

HAVING had occasion to measure some very small wires with a greater degree of accuracy than I was enabled to do by any instrument hitherto made use of for such purposes, I was led to contrive other means that might more effectually answer the end proposed. The instrument to which I had recourse is furnished with a single lens of about $\frac{1}{15}$ of an inch focal length. The aperture of such a lens is necessarily small, so that when it is mounted in a plate of brass, a small perforation can be made by the side of it in the brass as near to its centre as $\frac{1}{11}$ of an inch.

When a lens thus mounted is placed before the eye for the purpose of examining any small object, the pupil is of sufficient magnitude for seeing distant objects at the same time through the adjacent perforation, so that the apparent dimensions of the magnified image might be compared with a scale of inches, feet, or yards, according to the distance at which it might be convenient to place it. A scale of smaller dimensions attached to the instrument will, however, be found preferable on account of the steadiness with which the comparison may be made; and it may be seen with sufficient distinctness by the naked eye, without any effort of nice adaptation, by reason of the smallness of the hole through which it is viewed.

The construction that I have chosen for the scale is represented in fig. 1. (See Plate VI.) It is composed of small wires, about $\frac{1}{10}$ of an inch in diameter, placed side by side, so as to form a scale of equal parts, which may with ease be counted by means of a certain regular variation of the lengths of the wires.

The external appearance of the whole instrument is that of a common telescope, consisting of three tubes. The scale occupies the place of the object glass, and the little lens is situated at the smaller end, with a pair of plain glasses sliding before it, between which the subject of examination is to be included. This part of the apparatus is shewn separately in fig. 3. It has a projection at *a*, with a perforation through which a pin is inserted to connect it with a screw represented at *b*, fig. 2. This screw gives lateral motion to the object, so as to make it correspond with any particular part of the scale. The lens has also a small motion of adjustment by means of the cap *c*, fig. 2, which renders the view of the magnified object distinct.

Before the instrument is completed, it is necessary to determine with precision the indications of the scale, which must be different according to the distance to which the tube is drawn out. In my instrument, one division of the scale corresponds to $\frac{1}{1000}$ of an inch when it is at the distance of 16,6 inches from the lens; and since the apparent magnitude in small angles varies in the simple inverse ratio of this distance, each division of the same scale will correspond to $\frac{1}{1000}$ at the distance of $8\frac{1}{10}$ inches, and the intermediate fractions $\frac{1}{1000}$, $\frac{1}{1000}$, &c. are found by intervals of 1,66 inch marked on the outside of the tube. The basis on which these indications were founded in this instrument, was a wire carefully ascertained

to be $\frac{1}{200}$ of an inch in diameter, the magnified image of which occupied fifty divisions of the scale, when it was at the distance of 16,6 inches, and hence one division $= \frac{1}{50 \times 200} = \frac{1}{10000}$. Since any error in the original estimate of this wire must pervade all subsequent measures derived from it, the substance employed was pure gold drawn till fifty-two inches in length weighed exactly five grains. If we assume the specific gravity of gold to be 19,36, a cylindrical inch will weigh 3837 grains, and we may thence infer the diameter of such a wire to be $\frac{1}{200}$ of an inch, more nearly than can be ascertained by any other method. For the sake of rendering the scale more accurate, a similar method was in fact pursued with several gold wires, of different sizes, weighed with equal care; and the subdivisions of the exterior scale were made to correspond with the average of their indications.

In making use of this micrometer for taking the measure of any object, it would be sufficient at any one accidental position of the tube to note the number on the outside as denominator, and to observe the number of divisions and decimal parts which the subject of examination occupies, on the interior scale, as numerator of a fraction expressing its dimensions in proportional parts of an inch; but it is preferable to obtain an integer as numerator, by sliding the tube inward or outward, till the image of the wire is seen to correspond with some exact number of divisions, not only for the sake of greater simplicity in the arithmetical computation, but because we can by the eye judge more correctly of actual coincidence, than of the comparative magnitudes of adjacent intervals.

The smallest quantity, which the graduations of this instru-

ment profess to measure, is less than the eye can really appreciate in sliding the tube inward or outward. If, for instance, the object measured be really $\frac{1}{1100}$, it may appear $\frac{1}{1000}$ or $\frac{1}{1200}$, in which case the doubt amounts to $\frac{1}{10}$ part of the whole quantity. But the difference is here exceedingly small in comparison to the extreme division of other instruments where the nominal extent of its power is the same. A micrometer with a divided eye-glass may profess to measure as far as $\frac{1}{1000}$ of an inch; but the next division is $\frac{1}{1010}$ or $\frac{1}{990}$; and, though the eye may be able to distinguish that the truth lies between the two, it receives no assistance within $\frac{1}{2}$ part of the larger measure.

Fig. 3.

Fig. 1.

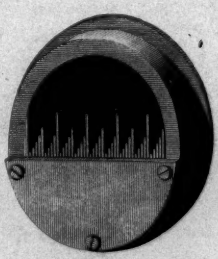
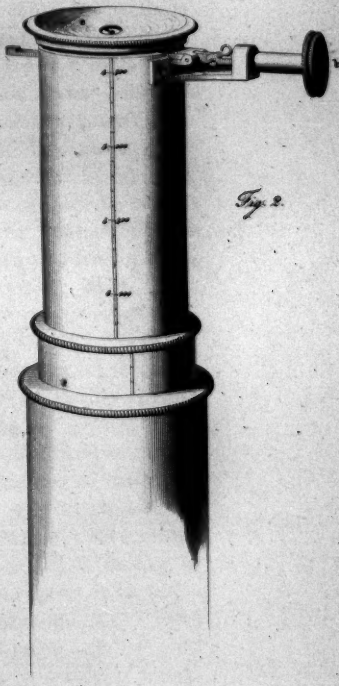


Fig. 2.



XVII. *Observation of the Winter Solstice of* 1812, *with the Mural Circle at Greenwich. By* John Pond, *Esq. Astronomer Royal, F. R. S.*

Read February 25, 1813.

THE weather this year at the period of the solstice was peculiarly unfavourable for astronomical observation; however, in the course of the month, I obtained nine observations of the sun; one of these proved defective, the result of the other eight, accompanies this communication. In my observation of the summer solstice, it will be seen that I assumed the arc ZP equal 38° 31′ 21″,15; by subsequent observation I conceive that I have somewhat improved this quantity, which I now assume 38° 31′ 21″,5, as resulting from 120 observations of Polaris.

The observation of the summer solstice thus corrected will give the mean obliquity of the ecliptic for January 1, 1813, 23° 27′ 51″,50, and the winter solstice 23° 27′ 47″,35.

There can be no doubt but this small discordance might easily be reconciled by a slight modification of BRADLEY's refractions, and perhaps ultimately it may be necessary to have recourse to this theory for its explanation; but I am unwilling to do this hastily, being now occupied in making an extensive series of observations of circumpolar stars, with a view of determining, if possible, whether BRADLEY's mean refraction does, or does not, require alteration.—As I propose making the discordance of the solstices the subject of a sepa-

rate paper, I shall not add any thing farther on the subject, excepting a recommendation to astronomers, to deduce their refractions from circumpolar stars altogether, and then examine the solstices with those refractions, and by no means to make the coincidence of the solstices a required proof of their accuracy.

Note. In the annexed computation the reduction to the solstice is computed from the *observed* right ascension of the sun, by this means the errors of the tables being avoided, observations at a considerable distance (even some weeks from the solstice) may be employed, particularly in the winter season, when the uncertainty from refraction is greater than the error which may be probably introduced into this part of the calculation.

1812.	Barometer:	Therm. In.	Therm. Out.	Refraction.	Observations as given by the Instrument.	Position of the Zero point, or Equation to be applied to obtain the N. P. D.	Equation to reduce the observed N. P. D. to Zenith Distance or position of the Zenith point on the Circle.	Semidiameter of the ⊙ greater than in the Nautical Almanack.	Reduction to the Solstice.	Solstitial Zenith Distance.	N. P. D.
						° ′ ″	° ′ ″	″	″	° ′ ″	° ′ ″
Dec. 6	30.19	41	38	3 21.1	⊙ UL 112 12 34.3	+ 0 6.5	38 31 15.0	+ 16 17.5	31.3	74 56 29.0	113 27 59.5
7	30.42	34	29	3 35.2	LL 112 51 44.4	6.5	15.0	16 17.3	37.4	44.7	45.2
9	29.81	29	24	3 36.5	LL 113 4 14.8	6.5	15.0	16 17.5	36 10.0	28.8	30.3
10	29.73	33	30	3 27.6	UL 112 37 19.5	6.5	15.0	16 17.6	30 36.8	26.5	43.0
11	29.84	35	34	3 36.0	LL 113 14 49.1	6.5	15.0	16 17.7	25 30.3	22.7	44.2
13	29.61	32	30	3 30.6	UL 112 51 13.0	6.5	15.0	16 18.0	16 41.8	28.4	49.9
15	29.44	32	31	3 39.3	LL 113 30 39.6	6.5	15.0	16 18.1	9 43.4	29.2	50.7
30	30.10	45	47	3 26.8	UL 112 50 38.8	6.5	15.0	16 18.8	1.7 18.0	27.4	48.9
					Mean of 8 Observations		- -	-	-	74 56 27.09	113 27 48.55
					Nutation + 7″.62 Parallax — 8″.50		⊙ Lat. — 0″.36 =			— 1.24	— 1.24
										74 56 25.85	113 27 47.55

XVIII. *On the Tusks of the Narwhale.* *By* Sir Everard Home, *Bart. F. R. S.*

Read February 18, 1813.

THE structure of many animals that inhabit the great Northern Ocean, is, even at this day, imperfectly known; this arises from those who have the best opportunities of making such enquiries not being fitted for them, or being too much engaged in pursuits of a different nature. Under such circumstances too much praise cannot be bestowed on the few individuals, whose zeal for science induces them to exert themselves in improving this branch of knowledge; to one of these, Mr. SCORESBY, jun. I am indebted for the means of making the following observations on the tusks of the narwhale.

Mr. SCORESBY told me, a year ago, that the female narwhale had no tusks, which astonished me; and the only reply I could make to such an assertion, was to beg that he would procure me a skull, that I might be satisfied of the fact. This he promised to do, and last summer sent me the skull of a female, in which there was no appearance whatever of tusks; and as the sutures were all united, there was every reason to believe the time of having teeth had elapsed, particularly as a male skull of the same size, and in which the sutures were not equally well united, had a tusk four feet long.

With such evidence before me, I was naturally led to adopt

the generally received opinion of the captains in the Greenland fishery, that the males had one tusk, and the females none; and as I imagined that I had cleared up a part of the natural history of this species of whale, which had hitherto been involved in obscurity, I proceeded to lay these observations before the Society. After I had done so, I found so many contradictory accounts among my friends, that I became staggered what to believe: some had seen two tusks of different lengths in the same skull, others believed they had seen two of the same length. To set the question at rest, my friend Mr. BROWN, Librarian to Sir JOSEPH BANKS, took the trouble of collecting all the books in Sir JOSEPH'S library, in which the subject is mentioned. In ANDERSON'S Description of Iceland, Greenland, and Davis's Straits, it is mentioned that, in 1684, DICK PETERSON brought to Hamburgh the skull of a female narwhale with two tusks, the left seven feet five inches, the right seven feet long, and that this skull had ever since been preserved there, and shewn to the curious. This account is copied by several later authors.

I found also, in TYCHO L. TYCHONIUS, an account, published in 1706, of a narwhale's skull with the left tusk seven feet long, and the right imbedded and completely concealed in the substance of the skull, nine Danish inches in length. The author takes some merit, and in my opinion deservedly, for having discovered it. A drawing of it *in situ* is annexed.

This information set me to work in sawing the skulls in the HUNTERIAN collection, to ascertain whether they contained rudiments of tusks not yet protruded from the substance of the bone, and the result of this investigation explains, in the most satisfactory manner, every thing that I have seen

written, or heard asserted upon this subject, and clears up any apparent difference between them.

In one male skull, in which the sutures were tolerably firmly united, the tusk in the left side is seven feet nine inches long; a small tusk, nine inches long, is imbedded in the bone on the right side, with a bulb or swelling at its root, and the point six inches from the front of the skull, which is quite solid, and has no external orifice.

In another male skull, which must have belonged to a younger animal, since the sutures are not completely united, the left tusk is four feet long, and the right one, concealed within the skull, is nine inches and three quarters long, and its point seven and a quarter distant from the front of the skull. In this specimen there is an external orifice leading down to the point of the young tusk, so that in this respect the small tusk is more advanced than in the older one, shewing that there is a great variety in the time of the second tusk coming forward.

The young tusks have not the spiral turns upon them, but are ribbed on the surface, and the ridges have a tendency to the left side. These are milk tusks, since they have come to their full growth, and are quite solid throughout their whole length, similar to the milk tusk of the elephant, which is however only two inches long before it is shed.

Upon sawing a full grown tusk in a longitudinal direction, I found that, contrary to what happens in the tusks of other animals, there is a hollow tube in the middle through the greater part of its length, the point, and the portion at the root, only being solid.

From these two specimens, there can be no doubt that the

left tusk appears commonly long before the right one, which corresponds with the accounts given by the captains employed in the Greenland fishery. One of these captains, who has been thirty-five voyages, informed me that he never saw a male narwhale with two tusks, except once from the mast head; the animal was rising out of the water, the left tusk was about six feet above the surface, and the point of the right tusk just out of the water, so that it appeared to him one-third the length of the left.

In the skull of the female sent me by Mr. SCORESBY, the sutures are more united than in the smallest of the males which I have described; there is no appearance whatever of tusks externally, but both on the right and left side there is an orifice in the bone, and when the skull was cut into, two small milk tusks were discovered of the same size and appearance, and exactly resembling those described in the male; they were eight inches long, and the points were only two inches and a quarter from the front of the skull, lying in a canal, of which the external opening was the orifice, so that they were nearer getting into the gum than those of either of the males; and there can be no doubt that the permanent tusks, which were to follow them, would be of equal lengths, or nearly so throughout their growth, as they were found to be in the skull at Hamburgh. We learn also, from this specimen, that the tusks in the female come much later than in the male, which explains the error the captains of the Greenland ships have been led into, of the females having no tusks.

Female skulls, with full grown tusks, must be rarely met with, since the only well authenticated account upon record

of a skull with two tusks of equal lengths, is that given by DICK PETERSON.

These facts make it necessary to take from this species of whale the name given to it by LINNÆUS, of Monodon Monoceros, since they prove that it is a very improper one.

The greatest length which has been given to the left tusk, before the right has cut the gum, is fifteen feet: this account is mentioned by EGEDE in his Natural History of Greenland, 1741.

The lower jaw, both in the male and female, has a rounded edge, in which there is no part from which teeth can grow.

EXPLANATION OF THE PLATE.

(See Plate VII.)

Fig. 1. The young skull of a male narwhale, shewing the permanent tusk in its socket, the milk tusk ready to be protruded.

Fig. 2. The female skull, with the two milk tusks ready to be protruded, having acquired their full size, and canals being formed through which the points are to pass out.

Fig. 3. A section of a milk tusk to shew that it is solid.

Fig. 4. The lower jaw, in which there is no place for teeth.

Fig. 5. A section of a full grown tusk, to shew the cavity in the middle, and that the parts at the point and at the root are solid.

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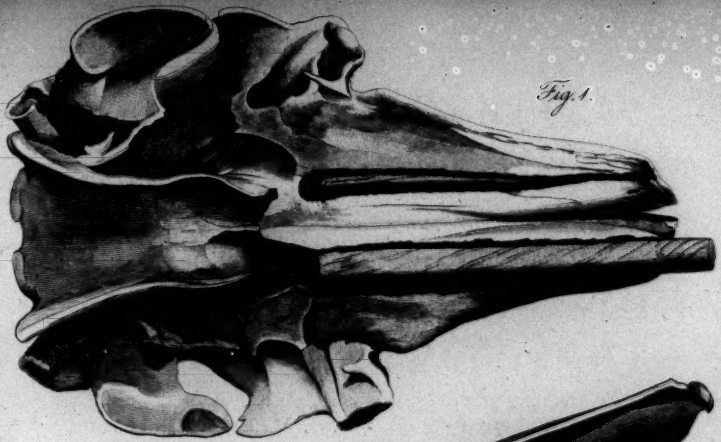

Fig. 1.

3 Inches to a Foot

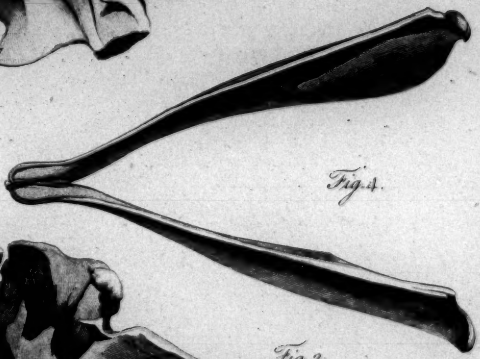

Fig. 4.

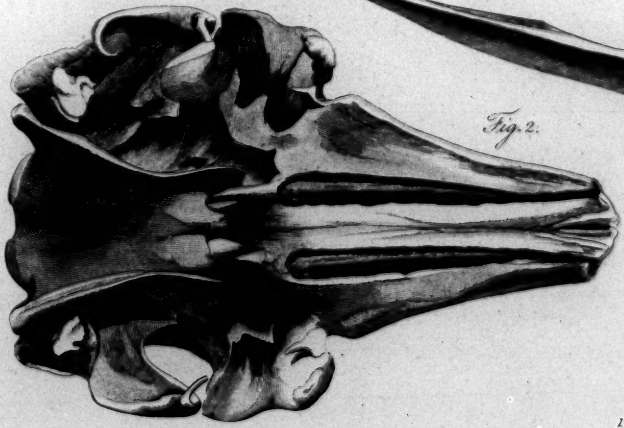

Fig. 2.

Fig. 5.

1 Inch & ½ to a Foot.

Fig. 3.

6 Inches to a Foot.

METEOROLOGICAL JOURNAL,

KEPT AT THE APARTMENTS

OF THE

ROYAL SOCIETY,

BY ORDER OF THE

PRESIDENT AND COUNCIL.

METEOROLOGICAL JOURNAL

for January, 1812.

1812	Time. H.	Time. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.		Winds. Points.	Winds. Str.	Weather.
Jan. 1	9	0	36	43	29,85	73	Rain this Month 0,779 Inches.	W	1	Hazy.
	3	0	39	46	29,78	71		W	1	Fine.
2	9	0	38	44	29,63	75		W	1	Fine.
	3	0	43	47	29,56	72		SSW	1	Fine.
3	9	0	37	45	29,44	70		SSE	1	Cloudy.
	3	0	41	44	29,32	70		S	1	Rain.
4	9	0	34	45	29,48	71		SW	1	Thick and Cloudy.
	3	0	39	47	29,44	70		E	1	Cloudy.
5	9	0	34	45	29,23	75		N	1	Snow.
	2	0	36	45	29,18	75		NE	1	Snow.
6	9	0	32	44	29,74	71		W	1	Hazy.
	3	0	43	47	29,75	69		W	1	Cloudy. [night.
7	9	0	33	45	29,63	71		W	1	Snow, much. Snow in the
	3	0	38	43	29,74	72		N	2	Cloudy.
8	9	0	34	45	30,08	71		N	1	Fine.
	3	0	37	47	30,16	70		NNE	1.2	Cloudy.
9	9	0	30	44	30,28	70		N	1	Foggy.
	3	0	36	47	30,21	67		W	1	Cloudy.
10	9	0	34	46	30,66	74		W	1	Cloudy.
	3	0	37	48	30,19	74		NNE	1	Foggy. Snow in the night.
11	9	0	35	47	30,15	74		W	1	Thick fog.
	3	0	38	47	29,99	71		W	1	Cloudy.
12	9	0	35	45	29,92	70		NNE	1	Hazy.
	3	0	39	45	29,90	70		N	1	Fine.
13	9	0	34	44	29,74	72		W	1	Thick and hazy.
	4	0	39	47	29,73	70		N	1	Cloudy.
14	9	0	37	47	30,02	72		W	1	Cloudy.
	3	0	40	49	30,10	69		W	1	Cloudy.
15	9	0	37	46	30,13	72		W	1	Cloudy.
	3	0	43	49	30,13	70		W	1	Hazy.
16	9	0	37	46	30,24	72			1	Foggy.
	3	0	38	49	30,18	72		E	1	Cloudy.

METEOROLOGICAL JOURNAL

for January, 1812.

1812	Time. H.	Time. M.	Therm. without.	Therm. within.	Barom.	Hygrometer.	Winds. Points.	Winds. Str.	Weather.
			o	o	Inches.	o			
Jan. 17	9	o	37	47	30,25	73	W	1	Cloudy.
	3	o	40	50	30,23	68	WNW	1	Cloudy.
18	9	o	35	48	30,26	69	W	1	Cloudy.
	3	o	44	49	30,24	71	W	1	Cloudy.
19	9	o	42	48	30,18	74	W	1	Rain.
	3	o	47	48	30,04	71	W	1.2	Cloudy.
20	8	o	38	47	29,97	68	NW	1	Fine.
	4	o	39	50	29,95	61	NNW	1	Fine.
21	8	o	32	47	29,84	65	W	1	Fair.
	4	o	36	51	29,83	61	W	1	Fine.
22	8	o	35	47	29,83	67	NW	1	Cloudy.
	3	o	38	51	29,82	67	N	1	Cloudy.
23	9	o	33	47	29,93	65	N	1	Cloudy.
	4	o	35	49	30,02	64	NE	1	Cloudy.
24	9	o	33	47	30,13	66	NW	1	Cloudy.
	3	o	38	50	30,12	63	NW	1	Fine, but rather hazy.
25	8	o	32	46	30,08	68	W	1	Cloudy.
	4	o	40	48	30,04	67	W	1	Cloudy.
26	9	o	41	47	30,00	75	SW	1	Rain.
	9	o	38	47	30,09	71	W	1	Fine.
27	9	o	41	46	30,03	75	SW	1	Rain.
	3	o	45	49	29,91	73	SW	1	Cloudy.
28	8	o	44	48	29,83	71	SSW	1	Cloudy.
	3	o	44	50	29,70	70	SW	1	Cloudy.
29	9	o	39	47	29,33	69	E	1	Cloudy.
	3	o	43	50	29,20	63	S	1.2	Cloudy.
30	9	o	42	48	29,25	73	S	1	Fine.
	4	o	45	52	29,32	72	S	1	Fine.
31	9	o	38	49	29,78	74	S	1	Fine.
	3	o	45	53	29,79	71	SE	1	Cloudy.

Rain this Month 0,779 Inches.

METEOROLOGICAL JOURNAL

for February, 1812.

1812	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer. °		Winds. Points.	Str.	Weather.
Feb. 1	9	0	41	51	29,77	74	Rain this Month 1,702 Inches.	E	1	Rain.
	3	0	45	52	29,64	71		SE	1	Rain.
2	9	0	44	50	29,66	72		SSE	1	Fine.
	4	0	46	51	29,46	72		SE	1	Rain, [gale of wind in the night.
3	8	0	42	50	29,58	73		SE	1	Fine and clear. A very heavy
	3	0	47	52	29,44	72		E	1	Cloudy.
4	9	0	46	51	29,36	75		ESE	1	Cloudy.
	3	0	48	54	29,44	74		S	1	Rain.
5	9	0	45	52	29,55	75		SE	1	Cloudy.
	3	0	46	53	29,50	75		E	1	Rain.
6	9	0	45	52	29,44	77		E	1	Thick and cloudy.
	4	0	45	53	29,47	75		NNE	1	Cloudy.
7	9	0	37	52	29,91	67		W	1	Fair.
	3	0	47	56	29,88	64		W	1	Cloudy.
8	8	0	39	52	29,69	70		W	1	Cloudy.
	4	0	43	53	29,75	67		NW	1	Rain.
9	9	0	40	52	29,99	68		S	1	Cloudy.
	4	0	41	51	29,99	64		S	1	Cloudy.
10	8	0	40	50	29,93	69		E	1	Cloudy and foggy.
	4	0	42	54	29,87	64		E	1	Fine.
11	8	0	35	50	29,85	71		E	1	Foggy.
	4	0	42	55	29,77	64		S	1	Fine.
12	8	0	46	51	29,54	75		SSW	2	Rain.
	4	0	48	53	29,42	74		S	2	Rain.
13	8	0	40	51	29,44	71		W	1	Fine.
	4	0	45	54	29,67	60		W	1	Fine.
14	8	0	43	51	29,54	73		SW	2	Rain.
	4	0	47	54	29,33	68		W	1	Cloudy.
15	8	0	41	51	29,63	67		W	1	Cloudy.
	3	0	45	55	29,68	60		WNW	1	Fine.
16	9	0	44	52	29,66	69		W	1	Cloudy.
	3	0	48	52	29,69	65		W	1	Cloudy.

METEOROLOGICAL JOURNAL

for February, 1812.

1812	Time. H.	Time. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer. °	Winds. Points.	Winds. Str.	Weather.
Feb. 17	8	0	48	52	29,59	76	W	1	Rain.
	4	0	50	54	29,40	71	SW	1	Rain.
18	8	0	42	53	29,81	68	W	1	Cloudy.
	4	0	49	55	29,95	70	W	1	Cloudy.
19	9	0	45	53	30,12	72	S	1	Cloudy.
	4	0	48	55	30,11	68	SW	1	Cloudy.
20	8	0	40	52	29,99	71	E	1	Fair.
	4	0	47	57	29,89	68	S	1	Cloudy.
21	8	0	47	54	29,77	74	S	1	Cloudy.
	4	0	53	57	29,59	67	S	3	Cloudy and squally.
22	9	0	44	53	29,48	72	S	3	Rain.
	2	0	48	54	29,48	69	SW	2	Cloudy.
23	9	0	47	52	29,58	67	W	1	Cloudy.
	5	0	48	54	29,74	63	W	1	Cloudy.
24	9	0	38	52	29,49	73	NNE	2	Rain. Snow in the night.
	4	0	44	56	29,84	65	W	1	Cloudy.
25	8	0	40	52	29,75	70	S	1	Cloudy.
	4	0	42	54	29,20	72	SSW	3	Rain.
26	9	0	46	51	29,37	72	W	1	Fair.
	4	0	42	52	29,49	69	W	1	Cloudy.
27	9	0	37	50	29,78	71	S	1	Cloudy.
	4	0	43	51	29,70	71	S	1	Rain.
28	9	0	37	50	29,68	72	W	1	Fair.
	4	0	43	54	29,64	65	SW	1	Fine.
29	9	0	36	50	29,57	72	E	1	Hazy.
	4	0	44	53	29,49	66	E	1	Cloudy.

Rain this Month 1,703 Inches.

METEOROLOGICAL JOURNAL
for March, 1812.

1812	Time. H.	Time. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer. °	Winds. Points.	Winds. Str.	Weather.
Mar. 1	9	0	41	50	29,46	70	E	1	Cloudy.
	4	0	43	50	29,50	64	E	1	Fair.
2	8	0	37	48	29,85	69	N	1	Fine.
	4	0	40	52	29,93	63	N	1	Fine.
3	9	0	35	48	29,93	67	E	1	Cloudy.
	4	0	41	50	29,88	70	S	1	Rain.
4	9	0	42	48	29,82	74	SW	1	Rain.
	4	0	50	51	29,77	76	W	1	Rain.
5	9	0	40	49	29,89	66	W	1	Fair.
	5	0	44	52	30,04	59	W	1	Fair.
6	8	0	40	50	29,70	73	WSW	1,2	Rain.
	4	0	49	52	29,79	60	W	1	Cloudy.
7	8	0	48	51	29,79	71	W	1	Cloudy.
	4	0	52	53	29,68	65	W	1	Cloudy.
8	8	0	41	51	29,89	69	W	1	Cloudy.
	4	0	44	51	29,95	63	NW	1	Cloudy.
9	9	0	38	49	30,26	65	N	1	Fair.
	4	0	41	54	30,28	65	N by E	1	Fine.
10	8	0	38	54	30,33	68	N	1	Cloudy.
	4	0	43	55	30,28	59	N	1	Fine.
11	8	0	36	49	30,27	71	N	1	Cloudy.
	4	0	42	51	30,27	61	E	1	Cloudy.
12	9	0	39	49	30,22	63	NE	1	Cloudy.
	4	0	42	51	30,10	61	W	1	Cloudy.
13	9	0	39	55	30,06	66	N	1	Fine.
	4	0	43	54	29,93	62	N by E	2	Rain.
14	8	0	38	49	30,04	70	NE	1	Cloudy.
	3	0	42	50	30,03	68	NE	1	Cloudy.
15	9	0	35	48	29,84	69	N	1	Fine.
	4	0	40	50	29,73	61	NW	1	Fine.
16	8	0	34	46	29,69	63	N	1	Cloudy.
	9	0	32	48	29,69	62			Cloudy.

Rain this Month 1,870 Inches.

METEOROLOGICAL JOURNAL
for March, 1812.

1812	Time. H.	Time. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer. °		Winds. Points.	Winds. Str.	Weather.
Mar. 17	8	0	33	46	29,73	62	Rain this Month 1,870 Inches.	N	1	Cloudy.
	4	0	36	50	29,76	60		N	1	Cloudy.
18	9	0	32	45	29,56	60		NW	1	Fine, rather hazy.
	4	0	35	45	29,40	60		E	1	Cloudy.
19	9	0	32	44	29,30	62		SW	1	Cloudy.
	11	0	33	48	29,31	66		W	1	Cloudy.
20	8	0	34	46	29,13	73		W	1	Rain. Snow in the night.
	5	0	42	49	28,94	74		W	1	Rain.
21	8	0	43	47	29,13	71		S	2	Rain.
	5	0	47	56	29,26	59		S	1	Fine.
22	9	0	44	49	29,49	71		W	1	Cloudy.
	4	0	47	50	29,63	68		E	1	Cloudy.
23	8	0	40	48	29,72	73		E	1	Cloudy.
	4	0	43	50	29,52	72		E	1	Cloudy.
24	9	0	41	49	29,14	76		NE	1	Cloudy.
	5	0	40	50	29,27	72		N	1	Rain
25	8	0	35	48	29,86	71		NNE	1,2	Cloudy. Snow in the night.
	5	0	37	57	29,89	59		N	1	Fine.
26	8	0	32	47	30,35	64		N	1	Fair.
	5	0	39	56	30,38	59		E	1	Fine.
27	8	0	38	48	30,19	67		E	1	Cloudy.
	4	0	44	50	29,92	60		SW	1	Cloudy.
28	8	0	49	49	29,50	75		SW	1	Cloudy.
	4	0	51	57	29,33	70		SW	1	Rain.
29	8	0	50	49	29,47	70		W	1	Cloudy.
	4	0	51	52	29,56	72		S	1	Rain.
30	8	0	51	51	29,38	76		W	1	Cloudy.
	4	0	55	54	29,46	70		W	2	Rain.
31	8	0	43	52	29,83	69		E	1	Cloudy.
	5	0	41	54	29,77	67		E	1	Cloudy.

METEOROLOGICAL JOURNAL

for April, 1812.

1812	Time. H.	M.	Therm. without.	Therm. within.	Barom.	Hygrometer.	Winds. Points.	Ser.	Weather.
			°	°	Inches.	°			
April 1	8	0	46	52	29,57	74	S	1	Rain.
	4	0	53	55	29,60	66	W	1	Cloudy.
2	8	0	50	53	29,64	73	W	1	Cloudy.
	6	0	52	55	29,57	73	W	1	Cloudy.
3	8	0	53	55	29,49	74	W	1	Cloudy.
	5	0	53	57	29,01	65	W	1	Cloudy.
4	8	0	47	55	29,64	69	S	1	Rain.
	4	0	52	57	29,82	67	S	1	Cloudy.
5	8	0	44	54	30,17	65	E	1	Cloudy.
	4	0	51	56	30,16	62	SW	1	Cloudy.
6	8	0	45	54	30,22	67	W	1	Hazy.
	4	0	49	57	30,20	59	SW	1	Cloudy.
7	8	0	45	54	30,00	62	SE	1	Cloudy.
	5	0	43	56	29,89	64	E	1	Rain.
8	7	0	40	54	30,06	70	E	1	Rain.
	5	0	42	57	30,14	56	E	1	Cloudy.
9	8	0	37	51	30,19	63	S	1	Fine.
	6	0	49	54	30,13	57	W	1	Cloudy.
10	8	0	38	52	30,04	56	E	1	Cloudy.
	6	0	43	53	30,00	57	E	1	Cloudy.
11	8	0	40	52	29,99	61	E	1	Cloudy.
	5	0	43	52	29,94	58	W	1	Cloudy.
12	8	0	41	51	29,90	61	W	1	Cloudy.
	5	0	46	53	29,91	55	N	1	Fine.
13	8	0	42	50	30,06	61	E	1	Cloudy.
	5	0	44	54	30,07	60	E	1	Fine.
14	8	0	41	50	30,04	63	E	1	Fair.
	6	0	44	55	29,96	62	E	1	Cloudy.
15	8	0	42	51	29,86	67	NE	1	Cloudy.
	5	0	46	58	29,79	58	E	1	Fine.
16	8	0	42	51	29,68	67	E	1	Cloudy.
	6	0	45	53	29,67	63	N	1	Cloudy.

Rain this Month 1,060 Inches.

METEOROLOGICAL JOURNAL

for April, 1812.

1812	Time. H.	M	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer. °		Winds. Points.	Str.	Weather.
Apr. 17	8	0	40	51	29,85	63		N	1	Fair.
	6	0	45	53	30,00	56		N	1	Fine.
18	9	0	40	50	30,06	63		N	1	Fine.
	10	0	42	53	30,13	56		N	1	Cloudy.
19	8	0	41	51	30,14	62		N	1	Cloudy.
	5	0	46	52	30,12	57		E	1	Fine.
20	8	0	40	50	30,07	63		W	1	Hazy.
	6	0	49	55	30,07	54		N	1	Fine.
21	8	0	44	52	30,21	63		N	1	Fine.
	6	0	53	55	30,16	54		W	1	Cloudy.
22	9	0	45	52	30,12	58		N	1	Cloudy.
	9	0	44	54	30,02	60		N	1	Cloudy.
23	8	0	40	51	30,06	62		N by W	1	Fine.
	11	0	42	53	30,06	60		N	1	Cloudy.
24	8	0	42	52	30,04	63		N	1	Cloudy.
	6	0	45	56	29,99	59		N	1	Cloudy.
25	8	0	42	53	29,91	63		W	1	Fine.
	4	0	45	55	29,75	65		W	1	Cloudy.
26	9	0	42	53	29,63	71		SW	1	Rain.
	11	0	42	52	29,65	65		E	1	Fine.
27	8	0	42	51	29,73	70		E	1	Cloudy.
	7	0	48	54	29,72	66		E	1	Rain.
28	8	0	48	53	29,70	72		E	1	Cloudy.
	6	0	48	55	29,77	71		ENE	1	Rain.
29	8	0	48	54	29,88	70		E	1	Cloudy.
	8	0	48	55	29,88	69		E	1	Rain.
30	8	0	47	53	29,85	76		E	1	Rain.
	7	0	49	55	29,90	73		E	1	Rain.

Rain this Month 1,060 inches.

METEOROLOGICAL JOURNAL

for May, 1812.

1812	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer. °	Winds. Points.	Str.	Weather.
May 1	8	0	48	55	30,11	72	W	1	Cloudy.
	6	0	52	58	30,09	64	N	1	Cloudy.
2	8	0	48	56	30,02	67	E	1	Cloudy.
	7	0	48	57	29,90	64	E	1	Fair.
3	9	0	47	56	29,78	68	N	1	Cloudy.
	5	0	53	56	29,74	60	NE	1	Cloudy
4	9	0	47	55	29,78	62	E	1	Fine.
	4	0	50	55	29,93	63	N	1	Cloudy.
5	8	0	49	55	29,93	65	NE	1	Cloudy.
	4	0	52	57	29,97	66	E	1	Cloudy.
6	8	0	48	56	30,07	67	E	1	Fair.
	6	0	54	59	30,05	61	E	1	Fine.
7	8	0	49	55	30,05	60	E	1	Cloudy.
	5	0	53	60	29,99	61	E	1	Fair.
8	8	0	53	57	29,92	63	E	1	Fair.
	5	0	66	63	29,85	52	SE	1	Fair.
9	8	0	63	61	29,81	60	S	1	Fair.
	6	0	60	63	29,76	62	SW	1	Cloudy.
10	8	0	57	61	29,88	62	W	1	Cloudy.
	11	0	54	60	29,88	71	W	1	Cloudy.
11	8	0	55	60	29,64	72	W	2	Cloudy.
	5	0	56	60	29,63	68	W	1	Cloudy.
12	8	0	54	60	29,62	65	W	1	Cloudy.
	6	0	57	61	29,58	61	S	1	Rain.
13	8	0	51	59	29,60	63	SSW	1	Cloudy. [at 2 PM.
	7	0	53	60	29,57	63	W	1	Fair. Thunder and hail-storm
14	8	0	51	58	29,64	65	W	1	Fine.
	10	0	52	60	29,75	62	W	1	Fine.
15	8	0	52	58	29,83	62	N	1	Cloudy.
	6	0	55	59	29,88	61	NE	1	Cloudy.
16	8	0	48	57	30,04	70	NE	1	Cloudy.
	4	0	54	58	30,04	71	E	1	Cloudy.

Rain this Month 1,932 Inches.

METEOROLOGICAL JOURNAL

for May, 1812.

1812.	Time. H.	Time. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.		Winds. Points.	Winds. Str.	Weather.
May 17	9	0	49	57	30,04	73		S	1	Cloudy.
	5	0	52	57	30,01	69		NE	1	Rain.
18	8	0	48	56	29,96	70		ENE	1	Rain.
	4	0	56	58	29,90	70		E	1	Cloudy.
19	8	0	54	56	29,85	76		E	1	Cloudy.
	4	0	62	59	29,74	63		NE	1	Fine.
20	8	0	58	58	29,68	77		W	1	Cloudy.
	4	0	62	59	29,71	61		W	1	Cloudy.
21	8	0	56	58	29,78	72		W	1	Cloudy.
	4	0	56	59	29,78	69		W	1	Rain.
22	8	0	51	58	29,99	63		W	1	Cloudy.
	4	0	54	58	30,09	59		N	1	Cloudy.
23	8	0	49	57	30,26	59		N	1	Cloudy.
	4	0	57	58	30,26	55		W	1	Cloudy.
24	8	0	52	57	30,32	60		N	1	Cloudy.
	5	0	55	57	30,27	58		S	1	Cloudy.
25	8	0	56	57	30,17	73		W	1	Cloudy.
	8	0	58	58	30,06	70		W	1	Rain.
26	9	0	60	58	29,95	60		W	1	Fine.
	4	0	65	62	29,86	53		SW	1	Cloudy.
27	8	0	63	61	29,62	60		S	1	Cloudy.
	4	0	65	65	29,60	57		S	1	Cloudy.
28	8	0	59	61	29,64	65		SSE	1	Cloudy.
	4	0	64	63	29,66	58		S	1	Cloudy.
29	8	0	61	62	29,64	70		SE	1	Cloudy.
	5	0	66	64	29,62	55		SSE	1	Cloudy.
30	8	0	58	62	29,84	61		W	1	Cloudy.
	4	0	65	64	29,87	55		S	1	Cloudy.
31	8	0	58	62	29,85	58		W	1	Cloudy.
	12	0	58	63	29,82	68		W	2	Rain.

Rain this Month 1,932 Inches.

METEOROLOGICAL JOURNAL

for June, 1812.

1812	Time. H.	Time. M.	Therm. without	Therm. within.	Barom.	Hygrometer.		Winds. Points.	Winds. Str.	Weather.
			o	o	Inches.	o				
June 1	8	0	58	60	29.78	58		S	2	Rain. Blowed hard all night.
	4	0	58	61	29,82	67		S	1	Rain.
2	8	0	55	61	30,13	66		SW	1	Fine.
	4	0	64	63	30,00	55		S	1	Cloudy.
3	8	0	59	61	30,05	65		W	1	Cloudy, thick, and hazy.
	4	0	62	62	30,05	62		W by N	1	Cloudy.
4	8	0	59	62	30,09	64		S	1	Fine.
	4	0	66	65	30,10	54		S	1	Fine.
5	8	0	60	62	30,13	60		E	1	Fine.
	4	0	66	65	30,11	55		E	1	Cloudy.
6	8	0	53	62	30,17	65		E	1	Cloudy.
	4	0	63	65	30,14	58		E	1	Fine.
7	8	0	53	61	30,24	62		S	1	Fair.
	4	0	67	64	30,22	53		E	1	Fair.
8	8	0	56	61	30,42	64		NE	1	Cloudy.
	4	0	62	63	30,41	59		N	1	Cloudy.
9	8	0	53	60	30,47	59		N	1	Cloudy.
	4	0	63	64	30,32	55		W	1	Cloudy.
10	8	0	55	61	30,24	60		N	1	Cloudy.
	4	0	56	62	30,29	59		N	1	Cloudy.
11	8	0	56	60	30,29	61		W	1	Cloudy.
	4	0	70	61	30,16	53		W	1	Fine.
12	8	0	60	63	30,09	64		W	1	Cloudy.
	3	0	69	66	30,02	56		W by S	1	Cloudy.
13	8	0	57	63	30,09	64		W	1	Cloudy.
	4	0	66	65	29,93	57		SW	1	Fair.
14	8	0	60	62	29,88	60		W	1	Cloudy.
	5	0	67	65	29,84	54		W	1	Fine.
15	8	0	61	63	29,86	63		SW	1	Cloudy.
	4	0	66	64	29,82	59		S	1	Fine.
16	8	0	57	63	29,80	61		SSW	1	Cloudy.
	4	0	63	64	29,73	54		SSW	2	Cloudy.

Rain this Month 1,756 Inches.

METEOROLOGICAL JOURNAL
for June, 1812.

1812	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer. °		Winds. Points.	Str.	Weather.
June 17	8	0	52	61	29,56	63		SSE	1	Cloudy.
	4	0	60	62	29,57	60		NW	1	Cloudy.
18	8	0	58	60	29,88	58		W	1	Cloudy.
	4	0	57	61	29,81	67		W	1	Rain. [in the night.
19	8	0	55	60	29,43	69		W	2	Fine. A violent squall of wind
	4	0	62	62	29,39	55		W	1	Fine.
20	8	0	55	60	29,38	53		SW	1	Fine.
	3	0	55	61	29,40	62		W	1	Rain.
21	8	0	55	60	29,58	63		S	1	Cloudy.
	5	0	61	61	29,57	59		SW	1	Cloudy.
22	8	0	52	58	29,74	63		W	1	Cloudy.
	4	0	60	61	29,83	57		W	1	Cloudy.
23	8	0	54	58	29,89	60		W	1	Cloudy.
	4	0	60	60	29,91	55		SW	1	Cloudy.
24	8	0	53	58	30,01	63		W	1	Cloudy.
	4	0	60	60	30,00	56		WNW	1	Cloudy.
25	7	0	55	58	29,99	63		W	1	Cloudy.
	5	0	61	60	29,91	56		W	1	Cloudy.
26	8	0	52	58	29,67	78		E	1	Rain.
	4	0	53	59	29,56	79		N	1	Rain.
27	8	0	51	57	29,92	60		NW	1	Fine.
	4	0	59	60	29,87	53		W	1	Cloudy.
28	8	0	52	58	29,86	63		N	1	Cloudy.
	3	0	57	60	29,96	54		NNE	1	Cloudy.
29	8	0	52	58	30,16	62		W	1	Fine.
	4	0	62	61	30,13	49		N	1	Fine.
30	8	0	57	58	30,06	60		W	1	Cloudy.
	4	0	60	59	29,99	55		W	1	Cloudy.

Rain this Month 1,756 Inches.

METEOROLOGICAL JOURNAL
for July, 1812.

1812	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer. °		Winds. Points.	Str.	Weather.
July 1	8	0	57	59	29,77	69		W	1	Rain.
	4	0	60	60	29,69	62		W	1	Rain.
2	8	0	58	59	29,48	66		W	1	Cloudy.
	4	0	63	63	29,44	55		W	1	Cloudy.
3	8	0	56	60	29,63	66		N	1	Cloudy.
	4	0	62	62	29,77	62		NE	1	Cloudy.
4	8	0	53	59	30,06	59		E	1	Cloudy.
	4	0	60	60	30,08	51		E	1	Cloudy.
5	8	0	56	59	30,09	59		SW	1	Cloudy.
	4	0	63	61	30,04	61		SW	1	Cloudy.
6	8	0	58	59	30,11	64		W	1	Cloudy.
	4	0	65	62	30,15	53		W	1	Cloudy.
7	7	0	59	61	30,29	64		W	1	Cloudy.
	4	0	67	64	30,30	55		N	1	Cloudy.
8	8	0	62	62	30,35	61		E	1	Fine.
	4	0	67	66	30,36	54		E	1	Fair.
9	8	0	59	62	30,40	64		N	1	Cloudy.
	4	0	67	67	30,35	53		E	1	Fair.
10	8	0	64	64	30,32	61		N	1	Fine.
	4	0	68	69	30,36	69		NNE	1	Cloudy.
11	8	0	60	59	30,44	56		NE	1	Cloudy.
	4	0	67	67	30,34	53		WSW	1	Fair.
12	8	0	64	65	30,15	61		NNE	0	Cloudy.
	3	0	64	59	30,17	54		NNE	1	Cloudy.
13	8	0	55	62	30,18	57		NE	1	Fine.
	4	0	62	64	30,16	51		E	1	Fine.
14	8	0	58	63	30,21	58		E	1	Cloudy.
	4	0	63	65	30,19	54		E	1	Cloudy.
15	8	0	56	62	30,16	61		W	1	Fine.
	4	0	65	65	30,15	50		N	1	Cloudy.
16	8	0	59	63	30,01	59		E	1	Cloudy.
	4	0	65	63	29,90	56		E	1	Cloudy.

Rain this Month 1,955 Inches.

METEOROLOGICAL JOURNAL
for July, 1812.

1812	Time. H.	Time. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer. °	Winds. Points.	Winds. Str.	Weather.
July 17	8	0	63	63	29,95	60	W	1	Cloudy.
	4	0	65	64	30,00	60	N	1	Cloudy.
18	8	0	63	64	30,16	64	E	1	Fair.
	4	0	69	68	30,13	50	W	1	Fine.
19	8	0	62	65	30,01	65	S	1	Cloudy.
	4	0	64	65	29,84	63	SW	1	Rain.
20	8	0	62	65	29,66	68	W	1	Cloudy.
	4	0	67	67	29,64	67	W	1	Rain.
21	8	0	59	65	29,88	61	W	1	Fair.
	4	0	65	65	29,95	55	S	1	Cloudy.
22	8	0	58	63	29,94	59	NE	2	Cloudy.
	4	0	55	64	29,95	62	N	2	Cloudy.
23	8	0	55	61	30,15	60	W	1	Cloudy.
	4	0	59	64	30,07	61	W	1	Cloudy.
24	8	0	55	62	29,91	62	WSW	2	Cloudy.
	4	0	63	63	29,78	65	S	1	Cloudy.
25	8	0	62	63	29,75	72	W	1	Cloudy.
	4	0	68	66	29,75	60	SW	1	Cloudy.
26	8	0	60	64	29,78	58	W	1	Fair.
	4	0	67	66	29,80	51	W	1	Cloudy.
27	8	0	58	63	29,84	60	W	1	Cloudy.
	4	0	64	63	29,61	66	E	1	Rain.
28	8	0	56	62	29,62	72	S	1	Cloudy.
	4	0	61	64	29,61	56	W	1	Cloudy.
29	8	0	57	61	29,58	62	W	1	Cloudy.
	4	0	63	64	29,55	55	W	1	Cloudy.
30	8	0	55	61	29,82	61	NW	1	Cloudy.
	4	0	63	63	29,89	59	W	1	Cloudy.
31	8	0	56	60	29,96	63	W	1	Fine.
	4	0	63	62	29,92	54	S	1	Fine.

Rain this Month 1,955 Inches.

METEOROLOGICAL JOURNAL
for August, 1812.

1812	Time. H.	Time. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer.		Winds. Points.	Winds. Str.	Weather.
Aug. 1	8	0	57	61	29,76	66		E	1	Cloudy.
	4	0	60	61	29,73	68		N	2	Rain.
2	8	0	57	61	29,86	66		NW	1	Cloudy.
	4	0	64	63	29,88	57		W	1	Cloudy.
3	8	0	58	61	29,77	76		SE	1	Rain.
	4	0	63	62	29,77	62		N	1	Cloudy.
4	8	0	56	61	29,83	69		N	1	Cloudy and thick.
	4	0	62	62	29,86	62		SE	1	Rain.
5	8	0	53	61	29,92	70		W	1	Rain.
	4	0	57	61	29,93	65		N	1	Cloudy.
6	7	0	54	60	29,95	69		N by W	1	Cloudy.
	4	0	60	62	29,93	63		NNW	1	Cloudy.
7	8	0	55	60	29,99	67		W	1	Cloudy.
	4	0	58	62	29,97	61		N	1	Cloudy.
8	8	0	56	60	29,91	67		N	1	Cloudy.
	4	0	57	60	29,89	65		NW	1	Rain.
9	8	0	55	60	29,95	65		NW	1	Cloudy.
	7	0	57	60	29,97	64		N	1	Cloudy.
10	7	0	55	59	29,98	65		N	1	Cloudy.
	5	0	58	60	29,96	63		N	1	Cloudy.
11	8	0	56	59	29,96	73		N	1	Rain.
	4	0	60	60	30,00	67		NNE	1	Cloudy.
12	8	0	54	59	30,13	61		N	1	Cloudy.
	4	0	56	60	30,14	58		N	1	Cloudy.
13	8	0	53	58	30,18	66		N	1	Cloudy.
	9	0	59	61	30,20	63		N	1	Fine.
14	7	0	54	60	30,22	66		N	1	Thick and cloudy.
	4	0	55	63	30,16	63		E	1	Cloudy.
15	7	0	57	61	30,16	65		SE	1	Cloudy.
	4	0	55	63	30,13	95		E	1	Fine.
16	8	0	59	64	30,04	67		E	1	Rain.
	4	0	58	64	30,03	65		E	1	Cloudy.

Rain this Month 1,480 Inches.

METEOROLOGICAL JOURNAL
for August, 1812.

1812	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer. °	Rain this Month 1,480 Inches.	Winds. Points.	Scr.	Weather.
Aug. 17	7	0	62	62	30,02	65		W	1	Fair.
	4	0	68	66	30,02	57		N	1	Fine.
18	8	0	63	64	29,96	65		W	1	Fair.
	4	0	69	71	29,90	54		E	1	Fair.
19	8	0	60	66	29,70	62		WSW	1	Fine.
	3	0	68	69	29,76	59		SW	1	Fine.
20	7	0	60	66	29,98	66		W	1	Fair.
	4	0	68	69	30,13	53		SW	1	Cloudy.
21	7	0	63	68	29,99	61		W	1	Cloudy.
	4	0	67	67	29,92	60		S	1	Cloudy.
22	7	0	61	66	29,96	68		W	1	Fine.
	4	0	67	68	30,02	54		W	1	Fine.
23	8	0	62	66	30,08	65		W	1	Cloudy.
	4	0	68	67	30,02	58		SW	1	Cloudy.
24	7	0	63	66	29,86	66		S	1	Cloudy.
	4	0	66	70	29,98	56		NNW	1	Cloudy.
25	7	0	57	65	30,15	62		W	1	Fine.
	4	0	66	68	30,13	54		S	1	Cloudy.
26	7	0	60	65	30,03	62		W	1	Hazy.
	5	0	67	66	29,97	57		N	1	Cloudy.
27	7	0	57	65	29,94	65		N	1	Fine.
	4	0	65	70	29,93	54		NE	1	Fine.
28	7	0	53	64	30,01	64		NNE	1	Cloudy.
	4	0	58	64	30,04	60		N	1	Cloudy.
29	8	0	53	62	29,99	66		N	1	Rain.
	4	0	56	62	29,99	68		NE	1	Rain.
30	8	0	55	61	30,01	72		N by E	1	Rain.
	4	0	59	65	30,04	69		N	1	Fine.
31	7	0	56	61	30,10	71		N	1	Cloudy.
	4	0	60	62	30,11	60		N	1	Cloudy.

METEOROLOGICAL JOURNAL

for September, 1812.

1812	Time. H.	Time. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer. °		Winds. Points.	Winds. Str.	Weather.
Sept. 1	7	0	55	61	30,18	63		N	1	Cloudy.
	4	0	60	62	30,19	57		N	1	Cloudy.
2	7	0	54	60	30,22	65		NNW	1	Cloudy.
	4	0	62	61	30,19	58		W	1	Cloudy.
3	7	0	57	60	30,12	67		W	1	Hazy.
	4	0	62	61	30,05	66		W	1	Cloudy.
4	7	0	57	60	29,90	65		NE	1	Hazy.
	4	0	62	61	29,86	60		E	1	Cloudy.
5	8	0	56	60	29,87	66		N	1	Fair.
	4	0	62	65	29,89	58		E	1	Fine.
6	7	0	56	61	29,96	71		N	1	Fine.
	3	0	64	65	29,98	55		E	1	Fine.
7	8	0	54	60	30,10	62		N	1	Cloudy.
	4	0	62	72	30,13	55		ESE	1	Fine.
8	7	0	52	61	30,13	65		E	1	Thick and cloudy.
	4	0	64	68	30,04	58		SE	1	Cloudy.
9	7	0	60	62	29,94	66		SE	1	Cloudy.
	4	0	63	64	29,90	65		SW	1	Cloudy.
10	7	0	58	62	30,03	68		W	1	Fine.
	4	0	64	68	30,14	54		NW	1	Fine.
11	8	0	56	62	30,21	54		W	1	Fine.
	4	0	64	68	30,24	55		WNW	1	Cloudy.
12	7	0	52	65	30,30	55		W	1	Cloudy.
	4	0	63	78	30,33	56		NW	1	Fine.
13	8	0	56	63	30,32	64		W	1	Fine.
	3	0	66	71	30,28	55		W	1	Fair, without a cloud.
14	7	0	54	63	30,25	64		W	1	Thick and hazy.
	5	0	63	71	30,21	55		W	1	Fair. No clouds.
15	7	0	51	64	30,16	63		W	1	Fair. No clouds.
	4	0	64	83	30,13	55		WSW	1	Fair.
16	7	0	53	64	30,00	65		W	1	Fair.
	5	0	64	72	29,95	56		W	1	Fair.

Rain this Month 0,634 Inches.

METEOROLOGICAL JOURNAL

for September, 1812.

1812.	Time. H.	Time. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer. °		Winds. Points.	Winds. Str.	Weather.
Sep. 17	7	0	55	64	29,91	65		W	1	Cloudy.
	4	0	59	63	29,90	66		N	1	Rain.
18	7	0	48	62	30,07	65		W	1	Fine, rather hazy.
	4	0	56	79	30,20	55		N	1	Fine.
19	7	0	44	60	30,27	63		W	1	Cloudy.
	4	0	57	69	30,23	53		W	1	Cloudy.
20	8	0	54	60	30,19	65		W	1	Fair.
	6	0	59	65	30,17	56		S	1	Fine.
21	7	0	55	61	30,05	62		SSE	1	Fair.
	4	0	62	83	30,01	55		SW	1	Fine.
22	7	0	55	62	30,00	65		W	1	Hazy.
	4	0	63	65	30,00	64		W	1	Cloudy.
23	7	0	54	62	30,04	71		NE	1	Fine.
	4	0	57	62	30,04	60		N	1	Cloudy.
24	7	0	50	60	30,00	66		W	1	Cloudy.
	4	0	55	62	29,99	56		N	1	Fine.
25	8	0	47	58	30,16	62		E	1	Fine.
	4	0	57	61	30,11	57		S	1	Cloudy.
26	7	0	55	60	30,10	74		W	1	Hazy.
	3	0	62	61	30,13	58		W	1	Cloudy.
27	8	0	57	60	30,14	72		W	1	Fair.
	10	0	62	62	30,07	70		W	1	Cloudy.
28	7	0	60	60	29,88	72		W	1	Cloudy.
	5	0	62	62	29,72	75		W	1	Rain.
29	7	0	54	61	29,97	69		N	2	Cloudy.
	4	0	57	61	30,01	65		E	1	Cloudy.
30	8	0	57	61	29,96	76		E	1	Cloudy.
	4	0	59	61	29,88	73		E	1	Cloudy.

Rain this Month 0,634 Inches.

METEOROLOGICAL JOURNAL
for October, 1812.

1812	Time. H.	Time. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer. °		Winds. Points.	Winds. Str.	Weather.
Oct. 1	7	0	58	61	29,80	77		E	1	Cloudy. [noon.
	4	0	59	62	29,79	72		W	1	Cloudy. A thunder-storm at
2	7	0	47	60	29,99	71		W	1	Fair.
	4	0	59	61	30,00	66		SW	1	Rain.
3	7	0	51	60	30,07	73		SW	1	Hazy.
	4	0	59	65	30,00	63		W	1	Fine.
4	8	0	52	60	29,95	72		S	1	Fair.
	4	0	60	66	29,93	62		S	1	Fair.
5	8	0	54	61	29,86	71		E	1	Foggy.
	4	0	61	62	29,76	67		S	1	Cloudy.
6	7	0	59	62	29,40	71		S	2	Fine.
	4	0	66	63	29,23	62		SE	2	Cloudy.
7	7	0	44	60	29,40	70		W	1	Fair.
	4	0	56	61	29,38	60		SSE	1	Cloudy.
8	7	0	55	60	29,17	75		SE	2	Rain.
	4	0	58	62	29,31	61		SW	1	Cloudy.
9	7	0	49	58	29,44	67		NE	1	Rain.
	4	0	54	59	29,48	65		SW	1	Fine.
10	7	0	50	58	29,40	70		SE	1	Cloudy.
	4	0	55	59	29,41	70		E	1	Cloudy.
11	7	0	48	58	29,36	72		W	1	Rain.
	4	0	54	57	29,31	69		W	1	Cloudy.
12	8	0	45	56	29,27	73		E	1	Foggy.
	4	0	51	56	29,22	71		W	1	Cloudy.
13	7	0	44	55	29,22	71		S by W	1	Cloudy.
	5	0	53	57	29,08	65		E	2	Rain.
14	7	0	49	55	29,88	72		SW	1	Rain.
	4	0	49	55	28,88	69		NNW	1	Cloudy.
15	7	0	45	54	29,19	70		W	1	Fine.
	4	0	52	55	29,22	65		W	1	Fine.
16	7	0	45	54	29,43	71		W	1	Fine.
	5	0	54	55	29,53	61		W	1	Cloudy.

Rain this Month 3,137 Inches.

METEOROLOGICAL JOURNAL

for October, 1812.

1812	Time. H.	Time. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer. °		Winds. Points.	Winds. Str.	Weather.
Oct. 17	7	0	43	54	29,63	70		E	1	Foggy.
	3	0	52	54	29,36	70		E	1	Cloudy. [in the night.
18	7	0	51	54	29,09	76		SW	1	Cloudy. Much wind and rain
	3	0	54	55	29,13	69		SSW	1	Rain.
19	7	0	51	55	29,77	68		W	2	Rain.
	4	0	55	57	28,63	66		SW	2	Cloudy.
20	7	0	49	55	28,83	65		W	1	Fine.
	4	0	54	56	28,99	58		NW	1	Cloudy.
21	7	0	45	54	29,51	64		NW	1	Cloudy.
	4	0	50	54	29,77	60		NW	1	Hazy.
22	8	0	50	54	29,56	68		S	2	Cloudy.
	4	0	55	58	29,44	66		W	1	Cloudy.
23	7	0	48	55	29,47	66		W	1,2	Cloudy.
	4	0	54	58	29,65	62		W	2	Cloudy.
24	7	0	44	56	29,97	68		W	1	Fine.
	4	0	53	58	29,97	62		W	1	Fine.
25	7	0	47	55	29,82	69		SSE	1	Fair.
	4	0	53	56	29,57	62		SW	1,2	Cloudy.
26	7	0	45	53	29,56	69		SW	1	Cloudy.
	4	0	50	58	29,69	60		W	1	Fair.
27	8	0	43	54	29,79	69		W	1	Cloudy.
	4	0	49	56	29,24	72		S	3	Rain.
28	8	0	42	53	29,44	67		W	1	Fair.
	4	0	47	56	29,47	61		W byN	1	Cloudy.
29	7	0	37	53	29,78	69		W	1	Fine, rather hazy.
	3	0	46	56	29,82	60		W	1	Fair.
30	7	0	44	53	29,79	67		E	1	Cloudy.
	4	0	49	55	29,73	64		SSE	1	Cloudy.
31	7	0	39	54	29,89	72		W	1	Fine.
	3	0	50	58	29,91	61		W	1	Fair.

Rain this Month 3,137 Inches.

METEOROLOGICAL JOURNAL

for November, 1812.

1812	Time. H.	Time. M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer. °		Winds. Points.	Winds. Str.	Weather.
Nov. 1	7	0	50	55	29,98	72		S	2	Cloudy.
	4	0	52	56	29,96	67		S	2	Cloudy.
2	7	0	51	55	29,90	76		N	1	Rain.
	4	0	52	57	30,01	66		W	1	Cloudy.
3	8	0	47	55	30,09	73		W	1	Rain.
	4	0	49	57	30,12	69		W	1	Fine.
4	7	0	43	53	30,14	69		W	1	Hazy.
	4	0	49	56	30,08	62		W by N	1	Cloudy.
5	7	0	43	55	29,86	67		NW	1	Fine.
	4	0	48	56	29,88	63		NNW	1	Cloudy.
6	7	0	37	54	29,85	68		W	1	Thick and cloudy.
	4	0	44	56	29,84	62		NW	1	Cloudy.
7	7	0	34	51	29,87	68		NW	1	Cloudy.
	4	0	41	54	29,88	65		W	1	Fine.
8	7	0	30	49	29,82	69		E	1	Thick and cloudy.
	11	0	36	50	29,79	66		E	1	Cloudy.
9	8	0	38	49	29,81	69		NE	1	Thick and cloudy.
	4	0	43	51	29,87	64		N	1	Cloudy.
10	7	0	34	49	30,11	69		E	1	Thick and cloudy.
	4	0	42	50	30,16	66		SE	1	Cloudy.
11	7	0	39	49	30,06	68		SE	1	Cloudy.
	4	0	45	52	29,95	64		SW	1	Cloudy.
12	8	0	40	49	29,81	72		E	1	Rain.
	4	0	42	52	29,74	73		E	2	Rain.
13	8	0	46	52	29,59	76		E	1	Thick and cloudy.
	9	0	48	54	29,35	75		S	1	Rain.
14	8	0	48	53	29,22	79		W	1,2	Cloudy.
	4	0	51	56	29,39	70		NE	1	Cloudy.
15	8	0	43	53	29,64	74		W	1	Fine.
	4	0	47	54	29,62	72		SSE	1	Cloudy.
16	8	0	45	53	29,31	75		E	1,2	Cloudy.
		0	45	50	29,20	72		E	2	Rain.

Rain this Month 1,855 Inches.

METEOROLOGICAL JOURNAL
for November, 1812.

1812	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer. °		Winds. Points.	Str.	Weather.
Nov. 17	8	0	43	53	28,99	75		E	1	Cloudy.
	4	0	43	56	28,99	76		NE	1,2	Rain.
18	8	0	42	53	29,15	73		NE	1	Cloudy.
	4	0	42	54	29,30	72		NNE	2	Cloudy.
19	8	0	35	51	29,66	68		N	1	Fair.
	4	0	40	53	29,80	70		N	1	Fine.
20	8	0	31	51	29,88	72		N	1	Foggy.
	4	0	39	53	29,87	70		SE	1	Cloudy.
21	8	0	35	51	29,98	66		N	1	Foggy.
	4	0	37	52	30,09	63		N	1	Fine.
22	8	0	33	49	30,33	71		N	1	Fine.
	3	0	38	51	30,37	70		NE	1	Fine.
23	8	0	27	46	30,38	70		S	1	Thick and hazy.
	4	0	47	50	30,30	70		S	1	Cloudy.
24	8	0	40	47	30,12	72		W	1	Fine.
	4	0	43	51	30,00	70		SW	1	Cloudy.
25	8	0	42	48	29,86	74		S	1	Cloudy.
	4	0	43	50	29,79	64		SW	1	Cloudy.
26	8	0	39	48	29,77	69		E	1	Cloudy.
	4	0	45	52	29,76	75		W	1	Cloudy.
27	8	0	46	51	30,07	76		W	1	Cloudy.
	4	0	45	53	30,17	76		W	1	Cloudy.
28	8	0	43	52	30,22	77		E	1	Rain.
	4	0	44	54	30,09	76		E	1	Cloudy.
29	8	0	42	51	29,93	75		E	1	Cloudy.
	4	0	47	52	29,93	75		W	1	Cloudy.
30	8	0	47	51	29,97	78		S	1	Cloudy.
	4	0	50	55	29,97	80		SW	1	Rain.

Rain this Month 1,855 Inches.

METEOROLOGICAL JOURNAL

for December, 1812.

1812	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer. °		Winds. Points.	Str.	Weather.
Dec. 1	8	0	49	53	29,91	79		S by E	1	Rain.
	4	0	50	54	29,82	75		S	1	Cloudy.
2	8	0	46	53	29,99	74		W	1	Cloudy.
	4	0	49	57	30,06	70		W	1	Cloudy.
3	8	0	47	54	30,10	76		E	1	Rain.
	4	0	48	57	30,12	76		E	1	Cloudy.
4	8	0	46	55	30,12	75		E	1	Cloudy.
	4	0	48	55	30,09	75		E	1	Cloudy.
5	8	0	41	54	30,11	71		E	1	Fine.
	3	0	42	55	30,12	66		E	1	Cloudy.
6	8	0	38	52	30,29	72		N	1	Fine.
	4	0	41	52	30,34	63		E	1	Cloudy.
7	8	0	32	48	30,54	65		E by S	1	Cloudy.
	4	0	36	52	30,53	65		E	1	Thick and hazy.
8	8	0	28	46	30,42	65		E	1	Cloudy.
	4	0	32	49	30,22	65		E	1	Fine.
9	8	0	25	45	29,95	68		W	1	Cloudy and hazy.
	4	0	35	49	29,95	63		NE	1	Cloudy.
10	8	0	31	44	29,91	75		W	1	Cloudy.
	4	0	35	48	29,81	72		W	1	Thick and hazy.
11	8	0	33	46	29,88	71		E	1	Cloudy. Snow in the night.
	4	0	34	47	29,98	70		E	1	Cloudy.
12	8	0	31	45	29,97	70		E	1	Cloudy. Snow in the night.
	4	0	32	47	29,89	67		E	1	Cloudy.
13	8	0	25	43	29,78	70		NE	1	Fine.
	4	0	31	44	29,73	69		NE	1	Fair.
14	8	0	27	42	29,72	72		NE	1	Cloudy.
	4	0	34	44	29,68	74		N	1	Cloudy.
15	8	0	30	40	29,66	68		E	2	Cloudy.
	4	0	32	43	29,52	68		ESE	2	Cloudy.
16	8	0	28	40	29,21	68		E	1	Cloudy.
	4	0	29	42	29,03	70		N	2	Cloudy.

Rain this Month 0,188 Inches.

METEOROLOGICAL JOURNAL

for December, 1812.

1812	Time. H.	M.	Therm. without. °	Therm. within. °	Barom. Inches.	Hygrometer. °	Winds. Points.	Str.	Weather.
Dec. 17	8	0	33	41	28,95	75	E	1	Cloudy. Much snow in the night.
	4	0	35	43	29,04	77	E	1	Cloudy.
18	9	0	33	42	29,25	72	E	1	Rain.
	4	0	35	44	29,29	76	W	1	Rain.
19	9	0	37	43	29,52	78	E	1	Cloudy and foggy.
	4	0	38	44	29,52	78	E	1	Foggy and cloudy.
20	9	0	36	44	29,58	78	E	1	Cloudy.
	4	0	36	43	29,56	74	E	1	Cloudy.
21	8	0	32	42	29,72	74	N	1	Cloudy.
	4	0	35	44	29,77	72	W	1	Cloudy.
22	8	0	37	43	29,82	75	E	1	Cloudy.
	4	0	38	45	29,87	78	E	1	Cloudy.
23	8	0	35	43	30,02	77	N	1	Cloudy.
	4	0	37	46	30,09	78	E	1	Rain.
24	8	0	33	43	30,30	73	N by E	1	Cloudy.
	4	0	36	46	30,33	72	N	1	Cloudy.
25	9	0	32	47	30,47	67	NE	1	Cloudy.
	4	0	33	47	30,45	67	N	1	Cloudy.
26	9	0	33	43	30,41	74	N	1	Hazy.
	4	0	37	47	30,37	73	NE	1	Cloudy.
27	9	0	33	44	30,50	75	NE	1	Cloudy.
	4	0	35	44	30,49	73	N	1	Cloudy.
28	9	0	32	42	30,49	72	W	1	Cloudy.
	4	0	38	44	30,46	73	W	1	Fine.
29	9	0	41	43	30,32	76	W	1	Cloudy.
	4	0	45	47	30,21	73	W	1	Cloudy.
30	9	0	43	46	30,18	74	W	1	Fine.
	4	0	45	48	30,15	71	W	1	Cloudy.
31	9	0	42	47	29,95	71	WNW	1	Cloudy.
	4	0	44	50	29,82	72	W	1	Cloudy.

Rain this Month 0,188 inches.

1812.	Thermometer without.			Thermometer within.			Barometer.*			Hygrometer.			Rain.†
	Greatest height.	Least height.	Mean height.	Greatest height.	Least height.	Mean height.	Greatest height.	Least height.	Mean height.	Greatest height.	Least height.	Mean height.	
	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Inches.	Inches.	Inches.	Deg.	Deg.	Deg.	Inches.
January	47	30	38,3	53	43	47,1	30,66	29,18	29,88	75	61	70,2	0,779
February	53	35	43,8	57	50	52,6	30,12	29,20	29,66	77	60	69,8	1,702
March	55	32	41,7	57	44	50,3	30,38	28,94	29,77	76	59	66,8	1,870
April	53	37	44,9	58	50	53,4	30,22	29,49	29,92	76	54	63,6	1,060
May	66	47	55,1	65	55	58,9	30,32	29,57	29,87	77	52	64,0	1,932
June	70	51	58,6	66	57	61,1	30,47	29,38	29,94	79	53	60,2	1,756
July	69	53	61,3	69	59	63,0	30,44	29,44	29,96	72	50	59,8	1,955
August	69	53	59,4	71	58	63,0	30,22	29,70	29,98	76	53	63,6	1,480
September	64	44	57,7	83	58	64,1	30,33	29,72	30,07	76	53	62,5	0,634
October	59	37	50,7	65	53	57,1	29,53	30,07	28,63	77	58	67,3	3,137
November	52	27	42,5	55	46	52,3	30,38	28,99	29,85	80	62	70,7	1,855
December	50	25	36,5	57	40	46,8	30,54	28,95	29,96	79	63	72,0	0,188
Whole year			49,2			55,8			29,79			65,8	18,348

* The quicksilver in the bason of the barometer, is 81 feet above the level of low water spring tides at Somerset-house.

† The Society's Rain Gage is 114 feet above the same level, and 75 feet 6 inches above the surrounding ground.

By another Rain Gage placed 11 feet 6 inches lower, the quantity of rain appears to have been 22,03 inches.

Variation of the Magnetic Needle, October, 1812, 24° 16′ 30″ West.